The Bristol Siddeley Olympus Marine Gas Turbine

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The author opens the paper with a discussion of the advantages to be gained by using suitably modified aircraft jet engines of the Olympus type as gas generators for marine gas turbines. The paper then describes the marine Olympus gas generator in some detail, with particular emphasis on the modifications which have been made to ensure satisfactory operation at sea level in a marine environment. The design features of the power turbine are then described, followed by an account of the control system for the complete engine.

A section then follows which discusses the performance of the engine with special reference to the effect of intake and exhaust conditions on power output and specific consumption. Some comments are made on the effect of service life on performance.

Engine installation arrangements are described in general and reference is made to noise suppression. The merits of various multi-engine installations are discussed. The installation section ends with some examples of actual ship installations.

The final section deals with possible future development of this type of engine and includes an account of the advantages both in specific power and thermal efficiency which can be obtained in the simple-cycle engine by exhaust-heat recovery.

INTRODUCTION

The emergence of the simple-cycle gas turbine engine based on established aero gas turbines has been one of the most notable features in the development of naval marine propulsion systems during the last eight years. It is significant that, after the start in the late 1950s with the Royal Navy *Brave* Class fast patrol boats, the adoption of this type of engine has spread rapidly in the last few years to most of the navies of the world and, perhaps even more significant, from comparatively small specialized engines for fast patrol boats to the main engines of much larger vessels of the frigate and destroyer type.

The reason for this is the acceptance by naval constructors and operators of the fundamental advantages of this type of engine. Basically, the new marine engine consists of a gas generator, which is simply a modified version of an established aircraft jet engine, supplying high-pressure hot gas to a specially-designed power turbine which converts the gas energy to shaft horsepower. The gas generator is by far the more complicated of the two components and it is mainly as the gas generator that the aircraft engine provides outstanding advantages.

These advantages can be enumerated as follows:

i) The aero engine design incorporates the experience in gas turbine design of the highest quality gained over a period of more than 20 years of continuous effort by first class design organizations.

ii) The actual aero engine itself has a background of thousands of hours of development running and in many cases hundreds of thousands of hours of operational experience. For example the Olympus aero engine, which is the gas generator of the marine Olympus engine, has a background of some 35 000 hours of test bench running and over 300 000 hours in flight.

iii) Manufacture in large numbers with comprehensive tooling has made the aero engine a comparatively cheap engine in terms of cost per horsepower.

iv) The aero engine is very compact and light.

v) The aero engine has been specially designed to be capable of rapid starts and accepting rapid changes in load.

vi) The aero engine is reliable and its degree of reliability is well authenticated.

vii) The aero engine usually has the best thermal efficiency which can sensibly be obtained in a simple-cycle engine due to the effort put into the design and development of its components.

However this is only one side of the picture. The duty for which it was designed causes it to have some disadvantages in its rôle as a naval marine engine. Amongst the more important are the following:

1) Like all high performance gas turbines it can only use distillate and gaseous fuels.

2) It has been brought to the point of perfection for aircraft use under environmental conditions very different from those of a marine engine. The most important of these are:

   a) it spends most of its life at high altitude where pressure and density are very low with subsequent reduction in aerodynamic excitation forces on its components and loading on its thrust bearings;

   b) it spends nearly all its life in a very clean atmosphere;

   c) the aero engine design does not usually provide the capability of accepting the high shock loadings which are required in naval vessels of the frigate or destroyer type.

Fortunately, by a comparatively minor programme of redesign and development, the deficiencies caused by these factors have been minimized as will be elaborated later in the paper. While it is not considered possible at this stage to make the engine suitable for burning residual fuels without almost completely destroying its overwhelming advantages, it has proved quite practicable to burn the heavier types of distillate fuel such as Diesel oil.

The power turbine design requires very special considera-

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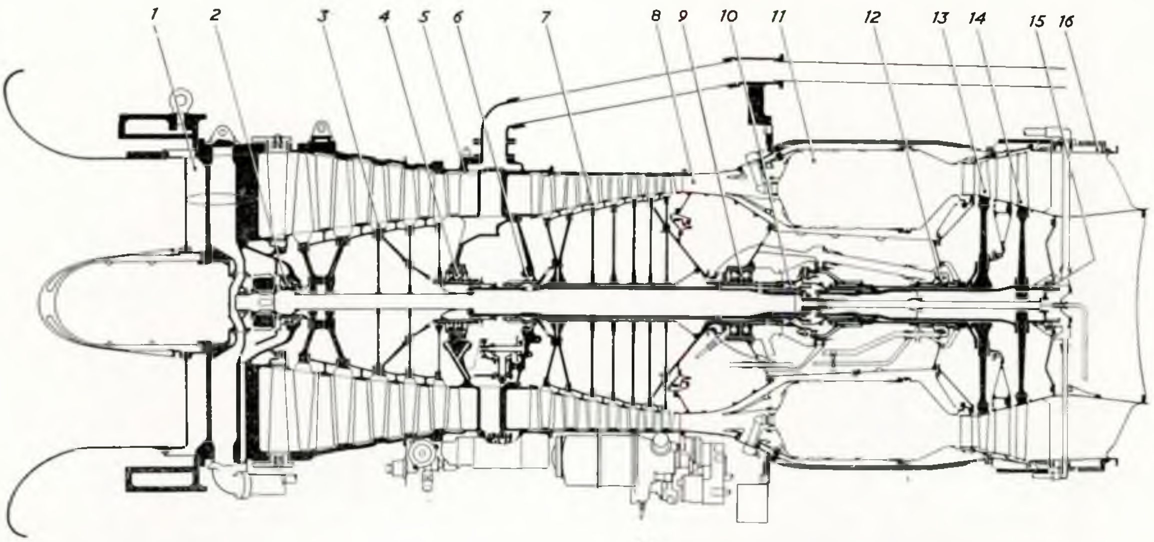


1) Air intake casing
2) Low-pressure compressor front bearing No. 1
3) Low-pressure compressor
4) Low-pressure compressor rear bearing No. 2
5) Intermediate casing
6) High-pressure compressor front bearing No. 3
7) High-pressure compressor
8) Delivery casing
9) High-pressure compresor rear bearing No. 4
10) Inter-shaft bearing No. 5
11) Flame tube
12) First stage turbine bearing No. 6
13) First stage turbine
14) Second stage turbine
15) Second stage turbine bearing No. 7
16) Exhaust annulus

FIG. 1—*Olympus gas generator—General arrangement*

tion to be given to the marine requirements as usually no suitable aero engine design exists. However the aero engine techniques of component design are invaluable in providing the necessary data for the design both as regards aerodynamic excellence and mechanical reliability.

The installation of the gas turbine marine engine in a vessel also needs careful attention. Here the aero engine background is of only limited use. However, the country is fortunate in having Naval staff who have pioneered gas turbine installations and it is largely through the knowledge and experience of the Ministry of Defence (Navy) and their agencies that these problems have been solved. The problems involve not only the gas turbine itself, but the combination of the gas turbine with other prime movers such as steam turbines and Diesel engines, and the control and manœuvring of the vessel with combined machinery of various types.

THE MARINE OLYMPUS GAS GENERATOR

A sectional arrangement of the marine Olympus gas generator is shown in Fig. 1.

The gas generator is developed from the Olympus 201 jet engine which is used in the Vulcan aircraft and is basically a straight-flow double-compound unit. It employs two mechanically independent axial flow compressors driven by separate axial flow turbines. The combustion system comprises eight flame tubes each with a burner contained within an annular casing.

The low-pressure (L.P.) and high-pressure (H.P.) compressors are arranged in tandem with the low-pressure compressor supplying air to the high-pressure compressor. The low-pressure compressor is driven by the second stage (rear) turbine and the high-pressure compressor is driven by the first stage (front) turbine giving an overall compression ratio of 10 : 1 with a mass flow of 230 lb/s maximum rating.

Referring to Fig. 1, the main components of the engine are as follows:

Air Intake Casing

This is an aluminium alloy casing which carries the low-pressure compressor front roller journal bearing, the nose fairing and the inlet guide vanes. Arrangements have been made for anti-icing the intake by means of hot air supplied from the high-pressure compressor when necessary. The air is supplied to a manifold incorporated in the intake casing and is directed between the double skin of the nose fairing and through the leading edges of the six hollow vanes which support the bearing housing and through the hollow inlet guide vanes.

Low-pressure Compressor

The low-pressure compressor is a five-stage axial flow unit and consists of an aluminium casing, cast in two halves, which houses the four rows of stainless steel stator blading in dove-tail section grooves machined within the casing diameter.

The rotor assembly is of disc type construction carrying the five rows of rotor blades and the whole assembly of discs and blades is made from stainless steel. The blades are retained in the discs by means of conventional fir-tree root fixings.

The compressor drive shaft is secured by its integral flange to the rear of the rotor assembly. A bearing seal positioned to the rear of the flange is followed by a matched pair of thrust ball bearings. The latter supports the rear end of the compressor rotor within the intermediate casing.

Intermediate Casing

Fitted between the low-pressure and high-pressure compressor is a cast aluminium intermediate casing which houses the low-pressure exit vanes and high-pressure inlet guide vanes. The casing has eight integral hollow vanes which support the centre section of the casing and incorporates a bleed connexion for the cooling air for the power turbine.

The centre section of the casing supports the low-pressure compressor rear bearing and the diaphragm at the rear of the casing supports the high-pressure compressor front roller bearing. Each compressor shaft is fitted with a spur gear which drives a mating gear located on the centre section diaphragm, thence by shafting in three of the hollow vanes to the gas generator accessory drives.

The attachment faces for the auxiliaries are arranged round the outer casing and embody drive housings in two groups, i.e. the low-pressure and high-pressure drives. The low-pressure group comprises the following drives:

i) low-pressure tachometer generator;
ii) low-pressure driven fuel pump.

The high-pressure group comprises the following drives:

1) high-pressure driven fuel pump;
2) gas generator main oil pump and four scavenge pumps;
3) high-pressure tachometer generator;
4) starter drive.

High-pressure Compressor

The high-pressure compressor is a seven-stage axial flow compressor manufactured entirely from stainless steel. Apart from the fact that the compressor casing is made in halves from stainless steel, the construction is very similar to that of the low-pressure compressor, the rotor being of disc construction with blades mounted in fir-tree roots.

The rotor is supported on its front end by the front rotor shaft which is screwed to the first and second stage discs. This shaft is located in the front roller bearing in the intermediate casing.

The rotor is supported on its after end on the rear rotor centre shaft which is carried on a matched pair of thrust ball bearings. This shaft also carries the compressor drive coupling.

An air supply is provided from the third stage of this compressor to supply cooling air for the rear face of the second stage turbine and for pressurizing bearing seals.

Delivery Casing

The delivery casing fabricated from stainless steel is interposed between the high-pressure casing and the combustion chamber outer casing and carries the matched pair of thrust ball bearings of the high-pressure compressor.

The unit comprises an inner and outer casing linked by eight hollow vanes through which the following services are directed:

a) oil supply to Nos. 4 and 7 bearings;
b) oil return from Nos. 4, 5 and 7 bearings;
c) No. 4 bearing housing vent to main engine breather pipe;
d) engine anti-icing air feed.

This casing is also the main mounting point for the gas generator.

Machined bosses round the outside of this casing accommodate the mountings for the eight duplex burners for the combustion chamber.

Housed within a chamber in the delivery casing is the coupling assembly that connects the high-pressure and low-pressure compressor to the first and second stage turbines respectively.

The low-pressure compressor coupling is fitted within the high-pressure coupling, and rotates independently on the inter-shaft roller bearing. External teeth of the compressor coupling engage with the internal teeth of the low-pressure turbine coupling. Thrust loads are transmitted through this coupling by means of the centre tube unit through the low-pressure turbine shaft. This centre tube is supported in a threaded steel spherical block in the compressor driving shaft, the swivelling movement of the block allowing for any malalignment.

The high-pressure compressor rear shaft accommodates the outer driven coupling in the same manner as that of the inner driven coupling, i.e. splined and retained by a ring nut secured with a locking washer, and receives the drive from the outer compressor turbine coupling internal teeth. The inter-shaft bearing outer track is positioned inside the outer compressor shaft coupling and is retained by circlips.

Extending forward from the outer turbine coupling are eight lugs each carrying an attachment nut and bolt, which secure a thrust-ring housing to the coupling. The coupling lugs are each fitted with two spring loaded plungers, one of which is engaged with a hole drilled in the bolt head. This arrangement, together with special nuts, ensures the security of the locating assemblies. Flexing of the high-pressure rotating assembly is permitted by the thrust-ring retaining bolts being of smaller diameter than the locating bolts in the coupling.

The coupling also supports an external labyrinth to form a seal with the coupling chamber housing.

Main Bearings

The gas generator rotating assembly is supported by seven main bearings, the positions of which are as follows:

i) the low-pressure compressor front roller bearing is housed in the rear of the air intake casing;
ii) the low-pressure compressor rear thrust double ball bearing is housed in the centre section of the intermediate casing;
iii) the high-pressure compressor front roller bearing is retained in the rear diaphragm of the intermediate casing;
iv) the high-pressure compressor rear thrust double ball bearing is supported in a housing in front of the coupling chamber unit;
v) the inter-shaft roller bearing is fixed between the low-pressure and high-pressure compressor couplings;
vi) the first stage turbine roller bearing is housed at the rear of the turbine inner drum;
vii) the second stage turbine roller bearing is housed in the exhaust annulus.

Combustion Chamber Outer Casing

The steel casing of the combustion chamber comprises top and bottom halves secured at the horizontal centre-line flanges with nuts and bolts. The casing is fitted between the delivery casing rear flange and the low-pressure turbine casing, with the turbine stator supporting ring interposed.

The bottom-half casing embodies the attachment mountings for the two igniter plugs and the turbine drain connexions, and also brackets for the two drain bosses.

Flame Tubes and Turbine Entry Duct Unit

Eight flame tubes are assembled around the annulus formed between the combustion chamber outer casing and the turbine inner drum. Each tube comprises two main units, i.e. the flame tube head and the flame tube unit. Nos. 4 and 6 tubes are fitted with steel inserts to accommodate the igniter plugs.

If necessary the flame tubes may be removed and replaced without removing the gas generator.

The flame tube head embodies a flanged connexion by which it is secured to the inner surface of the delivery casing, in conjunction with a retaining bracket bolted to a threaded boss on the flame tube.

The flame tube unit comprises a swirler which faces upstream and accommodates the duplex burner in its centre bore, two outer connecting flanges to link up with adjacent flame tubes and a locating ring which supports the rear end of the tube in the turbine entry duct.

The turbine entry duct unit is fitted between the combustion chambers and the high-pressure stator assembly. Its function is to support the rear ends of the flame tubes and the high-pressure stator front section, and also to direct the flow of gas to the turbine.

Turbine Assembly

The turbine assembly comprises the high-pressure turbine bearing support housing, the high-pressure turbine rotor and the low-pressure turbine rotor.

The bearing housing is supported by a diaphragm unit which is secured at its front end to the rear face of the combustion chamber inner casing. The rear end of this unit accommodates the turbine bearing and housing, the stationary portion of the turbine bearing seal, the stator support cone and the high-pressure turbine stators. Lubrication for the bearing is by means of an oil-jet assembly which is provided in the housing.

The high-pressure turbine disc is bolted to the large flange at the rear of the hollow turbine shaft, and forward of this flange are the front and rear seals. The front end of the shaft accommodates the compressor driving coupling assembly.

The hollow low-pressure turbine shaft passes through the bore of the high-pressure turbine shaft and a seal at its front end prevents hot air from the turbine passing between the shafts to the coupling chamber. The front end of the shaft also accommodates the turbine coupling which is secured on splines.

The high-pressure and low-pressure turbine blades are impulse/reaction type, shrouded at the tips. The root of each blade is of fir-tree form, which is located axially by a projection piece at its forward end and a locking tab at its rear end.

The low-pressure turbine bearing together with the relevant seal fitted between the bearing and disc, is secured to the wheel hub by a ring nut. A centre tube which passes through the bore of the shaft carries a connecting piece at its front end to locate the low-pressure compressor shaft. This tube provides positive location between the low-pressure turbine and the relevant compressor.

Exhaust Annulus

The exhaust annulus is mounted to the rear face of the low-pressure turbine casing and consists of an inner and outer steel ring connected by eight radial hollow vanes. At the front end of the annulus is a diaphragm which supports the low-pressure turbine shaft roller bearing and housing. Upper and lower connexions in the rear of the bearing housing connect with cooling-air and oil-drain pipes respectively.

Three of the eight hollow radial vanes are utilized as follows:

1) No. 1 vane conveys third stage high-pressure compressor air for the low-pressure turbine cooling and bearing seal pressurization;
2) No. 4 vane houses the oil-feed pipe to the oil-jet assembly in the rear bearing-housing cover;
3) No. 5 vane accommodates an oil-drain pipe from the bearing housing.

Special Features

It is not possible within the scope of this paper to describe in detail the design and the development of those components of the original Olympus 201 aero engine which have had to be changed to make the marine gas generator suitable for its new rôle.

However, a brief account of the major changes is of interest and these fall naturally into three categories:

a) material changes necessary for operation in a marine environment;
b) thrust bearing changes to enable long-term operation at sea level;
c) combustion equipment changes to give satisfactory smoke-free combustion using heavy distillate fuels and to provide long operating life under sea-level conditions of operation.

Material Changes

Material changes have been necessary in a number of the main casings of the aero engine, in the low-pressure compressor rotor blading and in some of the turbine blading.

The aero engine made extensive use of magnesium alloy castings to achieve minimum weight and these have been replaced in every case with similar castings in aluminium alloy. At the same time the inlet casing and the intermediate casing have been strengthened to cope with the higher shock loading conditions which can arise in naval service. No basic engineering problems are involved in the changes of these basically static parts.

The aero engine had aluminium alloy low-pressure compressor rotor blading and in view of the limited fatigue life of these blades in a salt atmosphere, a change to stainless steel was considered necessary. The same blade form was used and thus the blade-stress margin was increased. Careful strain-gauging of these new blades in an engine together with the normal practice of laboratory fatigue testing showed in fact that the margin of fatigue strength was now more than adequate. The extra weight of the blades however necessitated the redesign of the whole rotor, but here again the freedom to increase the rotor weight enabled a conservatively stressed design to be adopted. The completely new low-pressure rotor necessitated substantial test-bed running with very complete strain gauge investigation before it could be considered a proven design.

The comparatively minor, but important changes to the turbine blading were made with a high degree of confidence in view of the extensive experience at sea with the Proteus engine and the years of investigation into the effect of salt and sulphur corrosion on turbine-blade materials carried out in the company's laboratories and Government Research Establishments. The vital area is the high-pressure turbine stator and rotor blading and experience had shown that the materials used in the aero engine for these components, namely X.40 and Nimonic 105 respectively, were the best materials available. Their resistance to attack however could be appreciably improved by a surface treatment known as "pack aluminizing" which is in effect a method of impregnating the surface of the blade with aluminium. Under carefully controlled conditions this treatment, which is basically a heat treatment, can provide the desired improvement in corrosion resistance without impairing the basic creep and fatigue strength of the blades.

Bearing Changes

The two main thrust bearings in the original aero engine, namely, the low-pressure thrust bearing No. 2 and the high-pressure rotor thrust bearing No. 4 were both considered inadequate for continuous operation at sea level. No. 2 bearing was a single duplex type bearing and this was replaced by a twin duplex bearing of the same diameter, thus doubling its capacity. As No. 4 bearing was already a double duplex bearing it was necessary to increase its diameter with the consequent redesign of the components in its vicinity. It was found possible to accommodate a bearing of $8\frac{1}{2}$-in outside diameter instead of $7\frac{3}{4}$-in, giving a three-fold increase in its design "life" at full load.

Any change in a main thrust bearing in an engine can lead to trouble and a considerable amount of development running is necessary before one can be sure that the change has not introduced new problems. Fortunately this alteration was introduced earlier into the gas generator used for electrical generation and, by the time the marine gas generator appeared, ample experience with the new bearings had been obtained.

Combustion Equipment Changes

The problems associated with the Olympus combustion equipment when running continuously at sea level on Diesel oil had already been encountered and overcome in the gas generator used for electrical generation. In fact the industrial rôle posed the more difficult problem as, for electrical peak lopping purposes, the engine had to be smoke-free and it is required to operate always at its maximum rating. It was found that a radical redesign of the primary zone of the original flame tubes was necessary and that modified injector nozzles were needed. In addition mating surfaces in the combustion chamber had to be flame plated with tungsten carbide to avoid fretting wear.

The results of these modifications, both on the test bed and in operation in power stations, has been very satisfactory and the modified design can now be considered perfectly satisfactory for the marine requirements.

In all the foregoing modification programme the considerable experience gained by the gas generator used for electrical generation has been invaluable. Some 23 000 hours of running experience on 50 gas generators have already been obtained in industrial applications. The engines have been built to a varying modification standard, building up to the full "marine" specification as far as essential components are concerned. A gas generator to the latest standard has recently completed 1100 hours running at a power rating in excess of the maximum marine rating of the engine without any deterioration in performance. The strip examination showed the gas generator to be in excellent condition. Bearing in mind that in its marine application the maximum rating is only required for about five per cent of the engine life, it is apparent that the Olympus marine gas generator can be confidently expected to be a reliable unit.

THE POWER TURBINE

The marine gas turbine engine must be considered as a complete engine producing shaft power from fuel energy. There is therefore some danger in considering the gas generator and power turbine as two separate units but it happens, for a number of reasons, that it is convenient to make this division. The gas generator is basically a standard unit having a limited life and capable usually of being changed quickly when it requires overhauling. It is compact and light which makes it easy to handle for this purpose.

The power turbine on the other hand is designed for "infinite" life, is comparatively heavy, and is designed to be repaired when necessary *in situ* in the ship. It is usually specially designed for the purpose required and it is not unusual to find a number of power turbine designs for any one gas generator. Nevertheless it must be emphasized that for marine installations it is vital that the combination of the gas generator and the power turbine becomes a complete single power unit as far as its behaviour and operation in the ship is concerned.

This unity of design is in the author's opinion much more important in the case of the marine engine than an industrial engine and for this reason the author believes that the best engine will result when one company is responsible for the complete engine. With good technical collaboration however between two competent companies, it is possible to combine the gas generator with a power turbine designed by a second company. In fact the very first marine Olympus gas turbine was designed in this way.

This was the Bristol Siddeley/Brown, Boveri marine Olympus gas turbine which was ordered by the German Federal Government in May 1962 for shore proving trials. The gas generator with its mounting was provided by Bristol Siddeley and the two-stage power turbine by Brown, Boveri of Mannheim. The complete engine control system was designed and supplied by Bristol Siddeley and the closest degree of collaboration was maintained between the two companies throughout the design process and indeed throughout the assembly and testing of the final engine.

After passing its acceptance trials successfully in Mannheim the engine was delivered to the Federal Government Naval Yard at Kiel in January 1965 where it is undergoing endurance trials. On its makers' trials at Mannheim the engine more than met the guaranteed performance figures. The engine has run 550 hours up to date at Mannheim and Kiel.

Shortly after the Brown, Boveri order the British Ministry of Defence ordered a complete Olympus gas turbine expressly for providing the gas turbine power for the new Type 82 Guided Missile Destroyers which are a COSAG design having an Olympus gas turbine and a steam turbine driving each of two shafts.

This engine was given the type number TM.1 and the complete engine is shown in Fig. 2.

The design criteria for the TM.1 power turbine were:

i) the turbine had to be as robust and simple as possible consistent with having a high efficiency;
ii) the rotational speed could be chosen to satisfy the above condition as a main reduction gear would be required whatever the rotational speed;
iii) the turbine had to stand high shock loads without distress;
iv) the main bearings had to be accessible for inspection without dis-assembling the unit;
v) the design had to have an unlimited life at the ratings required.

The resulting design is shown in Fig. 3.

The whole unit is carried on a heavy steel base plate (5) which is mounted off the ship's structure at four points.

Separately mounted on the base plate are:

a) the turbine stator system and inter-turbine duct (3) and exhaust volute (2);
b) the steel pedestal which carries the turbine rotor shaft (1).

The turbine stator system is carried off a steel support ring (4) integral with the base plate by means of a segmental cone. The stator casing is a centri-spun stainless steel casting split on the horizontal centre line to facilitate fitting, removal and inspection of the fifty-six forged Ni.80 stator blades.

The single stage rotor consists of a row of seventy-one Ni.80A forged blades attached to a vacuum-melted forged disc. The blades are attached to the disc by conventional fir-tree root fixings.

The bladed disc is located on a stub shaft by "Hirth"

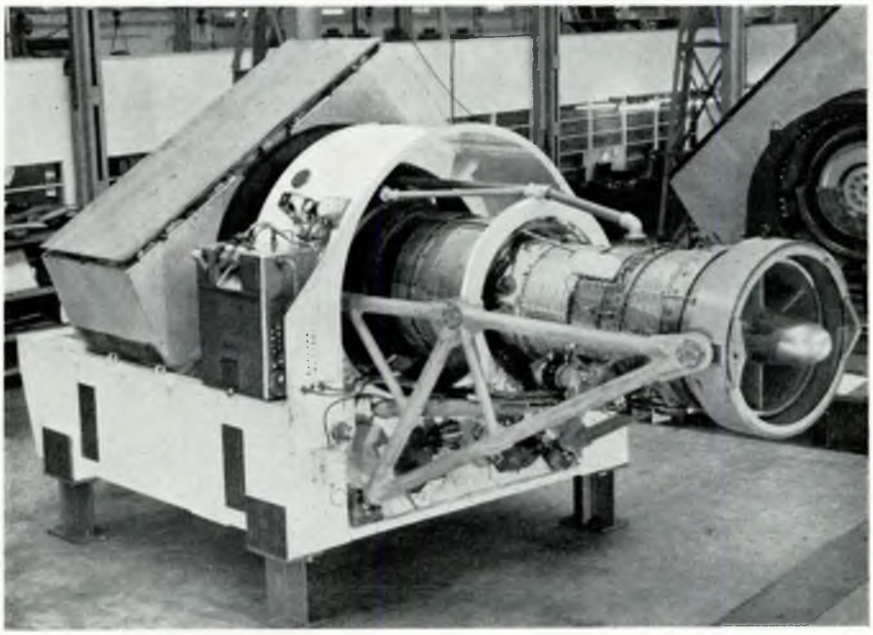


FIG. 2—*Olympus gas turbine engine—Type TM.1*

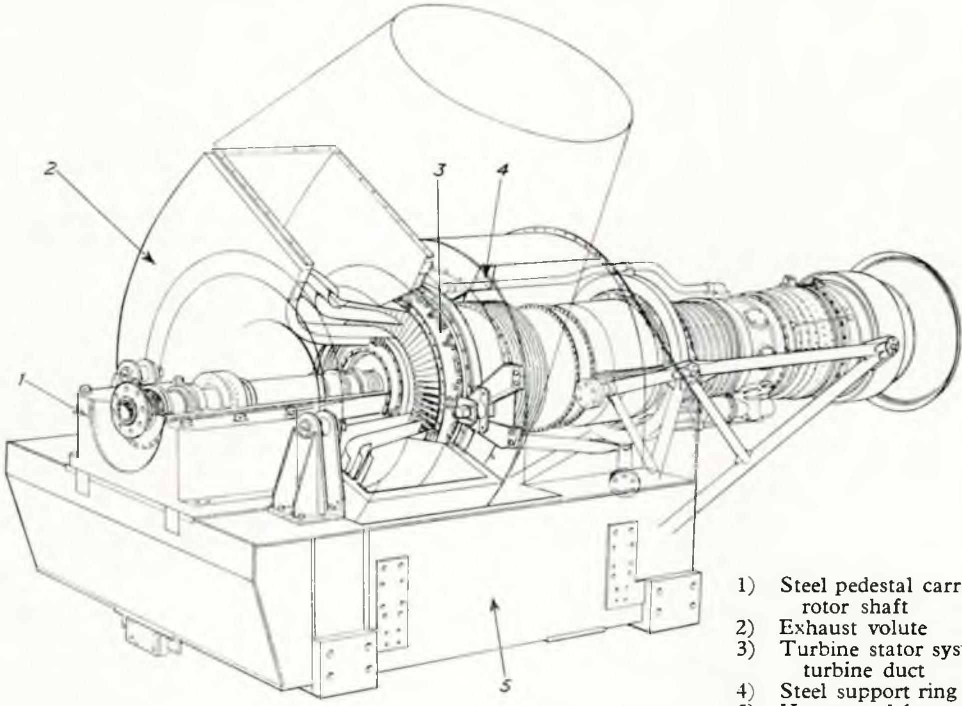


FIG. 3—*TM.1 power turbine*

couplings centralizing the disc and permitting differential growth. This assembly is secured by a single nut at the forward end of the stub shaft. The main shaft is bolted to the stub shaft and supported by two substantial journal bearings housed in the bearing pedestal. The pedestal is designed to contain the axial-thrust loads from the double-acting thrust bearing which is located in the pedestal. Each bearing can be examined individually by removing the easily accessible bolts in the pedestal covers.

The main shaft also carries the overspeed trip plate which operates the overspeed trip mechanism mounted on the pedestal. The trip plate is designed to operate by centrifugal force when the turbine shaft exceeds its maximum design speed by ten per cent. The trip ring triggers off a mechanism which closes the high-speed shut-off cock, thus stopping the supply of fuel to the gas generator. This mechanism is in fact the ultimate safeguard against power turbine overspeeding and it is entirely independent of any accessory drives or other governors in the main fuel-control system.

After leaving the power turbine the exhaust gas is diffused and then directed into the exhaust volute by cascade vanes. The exhaust volute is connected directly to the ship's uptake and silencing system. A flexible bellows attached to the exhaust volute flange caters for deflexions imposed through thermal distortion or hull movements and prevents uptake loads being transmitted to the power turbine.

The gas generator itself is carried off the front of the power turbine assembly by means of two tubular cantilever

FIG. 4—*TM.2 power turbine*

structures each mounted on two ball joints. A bellows joint is provided in the duct to the power turbine and the gas generator and the cantilever structures are arranged so that the deflexions of the bellows under shock load are minimized. Due to the resilience of this structure shock accelerations experienced by the gas generator are lower than those arriving at the power turbine.

This arrangement simplifies the removal of a gas generator for repair as the tubular support frames can be swung sideways clear of the gas generator, thus allowing the gas generator to be lowered on to a suitable trolley. Replacement of the gas generator is simple as no alignment problems are involved, the only connexion with the power turbine assembly being the bellows joint.

This arrangement is shown clearly in Figs. 2 and 3.

While the TM.1 gas turbine has succeeded in satisfying all the design requirements, the resulting unit is heavier than is necessary for most applications and due to the arrangement of the bearing pedestal the exhaust volute is wider than is desirable as it is restricted in its fore and aft length.

A modified version of the design, which is referred to as the TM.2 turbine, has therefore been developed. This is shown in Fig. 4.

Exactly the same rotor system is used, but the exhaust volute has been made longer and narrower and the support bearing pedestal has been eliminated. The main shaft bearings are now carried in a tube mounted inside the exhaust volute and the loads taken through supports in the lower part of the volute to the base plate. Although this design eliminates the possibility of direct access to the main bearings, these are readily available for inspection by withdrawing the central tube, complete with rotor shaft and its bearings, from the base plate and exhaust volute assembly. This has resulted in a substantial saving in width and also a saving in weight without impairing in any way the capability of the unit to resist shock loading.

However, the new design is such that under circumstances where high shock loads are not encountered, further substantial weight saving can be achieved by changing the mounting arrangements which are not an integral part of the design.

CONTROLS AND FUEL SYSTEM

The fuel-control system for the marine Olympus engine has been specially designed to provide the essential characteristics required with maximum simplicity.

The system involves two separate methods of controlling the fuel flow; firstly by means of a throttle and secondly from the speed of the power turbine. In addition safety devices are provided which prevent the power turbine or either of the gas generator rotors being damaged by overspeeding and which prevent the gas generator being damaged by excessive temperature.

The complete fuel system and control system is shown in Fig. 5.

General Description of Fuel System

Filtered fuel is supplied to the gas generator from the ship's fuel supply system. A boost pump and an associated relief valve are included in the system to provide a controlled pressure at the engine inlet under all operating conditions. The fuel is then fed to two positive-displacement, variable-stroke, multi-plunger type engine-driven fuel pumps, via a 25 micron fuel filter. One of the pumps is driven by the low-pressure compressor and the other by the high-pressure compressor. The plungers of each pump are operated by a camplate, the angle of which can be varied by the action of a servo-system operating a piston to move the camplate. The servo-system, which is monitored and controlled by the fuel-control system, varies the stroke of the plungers, as shown in Fig. 5 and controls the fuel flow to the engine. An hydraulically operated overspeed governor is incorporated in each fuel pump to prevent the compressor exceeding its limiting speed.

From the engine-driven fuel pumps the fuel is distributed to the eight duplex burners, one mounted in each flame tube, via the high-speed shut-off cock and a distributor which is mounted on the high-pressure compressor casing. Each burner has a primary atomizer (which is used on its own during starting) and a main burner atomizer. The distributor functions by metering fuel individually to the main burner atomizers, and controls the opening of the main burner. Additionally, the distributor acts as a pressure increasing valve to give the desired throttle characteristic.

A fuel-injection cylinder supplies fuel to the gas turbine at a controlled rate for starting purposes. This cylinder, which is normally charged, is pneumatically operated and is

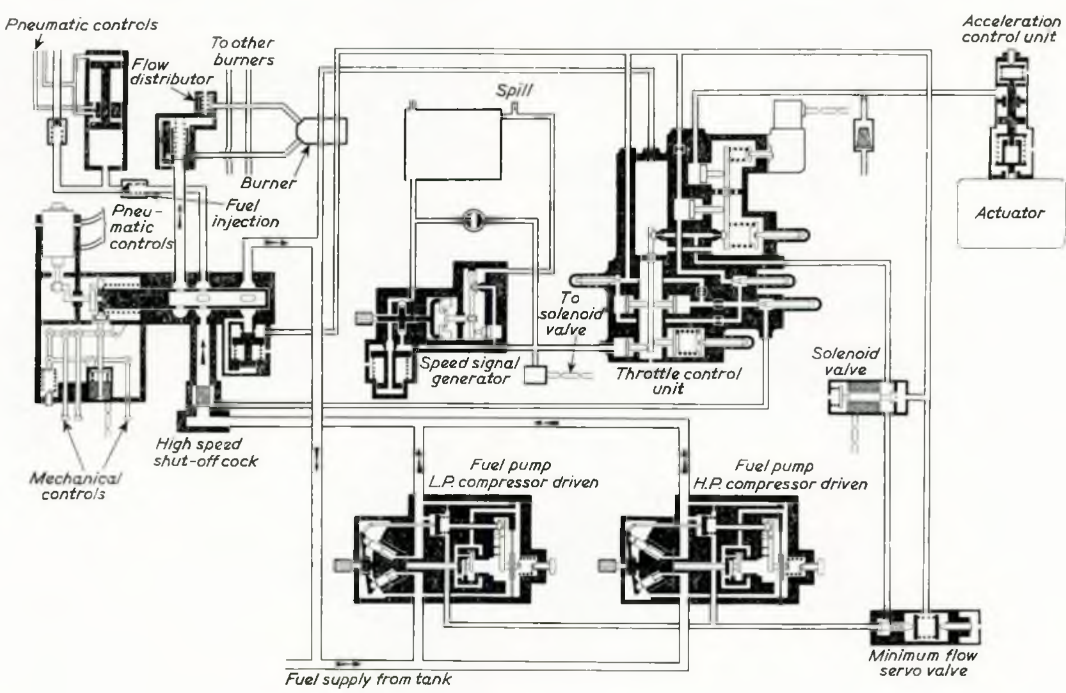


FIG. 5—*Marine Olympus fuel-control system*

programmed into the start cycle to inject fuel to the gas generator via the high-speed shut-off cock. As the gas generator speed increases, the main fuel pumps take over the supply function. The fuel-injection cylinder is automatically replenished with Diesel fuel from the low-pressure fuel supply system in preparation for the next start.

Description of Fuel-control System

The throttle control unit is contained in the fuel-control box, which is mounted on the power turbine frame. The unit incorporates two pivoted operating arms, i.e. the throttle arm and the governor arm. The throttle arm controls the gas generator acceleration and speed setting, and the governor controls the power turbine maximum speed, both arms controlling the fuel pump servo-pressure.

When the engine is running at a steady speed, the throttle arm is in equilibrium, controlled by constant values of compressor delivery, fuel pump delivery and servo-pressures. To accelerate the gas generator, or to change its power setting, a signal is transmitted to the throttle actuator. The output from the actuator is a mechanical signal to the acceleration control unit which is also contained in the fuel-control box. The acceleration control unit modifies the compressor delivery pressure signal to the throttle arm, upsetting its equilibrium to increase the pump servo-pressure, which increases the fuel flow to the gas generator. Equilibrium is gradually restored to the throttle arm by feed-back of compressor and pump delivery pressures on to the arm. The gas generator has then reached the selected running condition.

The mechanical displacement of the acceleration control lever has a linear relationship with pump delivery pressure. By suitable arrangement, extremely accurate setting and control of gas generator speed can be achieved.

Governor control is achieved by bringing the governor arm into equilibrium under pump delivery, servo and speed signal pressures, and a fixed spring datum. Pump delivery pressure is modified to act on both sides of the governor arm to give a steady state droop of eight per cent between the "full load" and "no load" conditions. The fixed spring datum is manually adjustable to give a top speed governing range of +5 per cent to −10 per cent of maximum power turbine speed.

An increase in power turbine speed above the pre-set datum causes the speed signal generator to transmit an oil signal proportional to the square of the power turbine speed to the governor arm. This upsets the equilibrium of the arm, causing a bleed-off of pump servo-pressure, thus reducing fuel flow to the engine and reducing the power turbine speed. Equilibrium is restored when the power turbine speed reduces to its governed level.

The governor will control only relatively slow changes in power turbine speed. To avoid overspeed due to a sudden load reduction, a partial overspeed switch is used. This energizes a solenoid valve to bleed off pump servo-pressure rapidly, to reduce the gas generator to zero power, when the power turbine reaches five per cent overspeed. When normal speed is restored, the solenoid valve is de-energized and power is restored at a controlled rate.

The fuel supply to the gas generator can be shut off in less than 0·050 seconds by the high-speed shut-off cock. This unit consists of a rotary valve opened by a pneumatic actuator, the operation of which is programmed into the "start" cycle. The valve remains latched open and armed when the actuator retracts, and is closed manually, or by an electric signal to a solenoid, by removing the latch pin which allows rapid closure under spring action.

Temperature control is effected by means of eight thermocouples fitted in the inter-turbine duct between the gas generator and the power turbine. A temperature control unit senses the average thermocouple temperature reading, compares the average with a pre-set datum to send an amplified signal to an actuator which operates on the throttle arm in the throttle control unit to bleed off pump servo-pressure, and thus reduces the gas generator speed and maintains the efflux temperature at an acceptable level. The temperature control unit also includes a trip to the high-speed shut-off cock if the exhaust temperature exceeds 50° C (90° F) above the normal maximum controlling temperature of 620° C (1148° F).

PERFORMANCE

The maximum power that can be obtained from the Olympus gas turbine engine depends upon the maximum cycle temperature at which the gas generator can operate safely with an adequate life between overhauls. The conception of repair by replacement of the gas generator is fully accepted but obviously there is a practical lower limit to the time between overhauls which must be met. For an engine used mainly for boost purposes, an initial target of 3000 hours between overhauls is generally acceptable and for naval vessels in general a figure of 6000 hours is probably reasonable for cruising engines.

Most of the operating experience gained with the Olympus gas generator has been in the field of electrical generation where a total of some 23 000 hours has already been achieved. In this application the engine normally operates all the time at full power whereas in naval applications full power is normally required for only about five per cent of its running time. The maximum power ratings therefore demonstrated in generator sets gives a conservative figure for the maximum power rating in a naval engine.

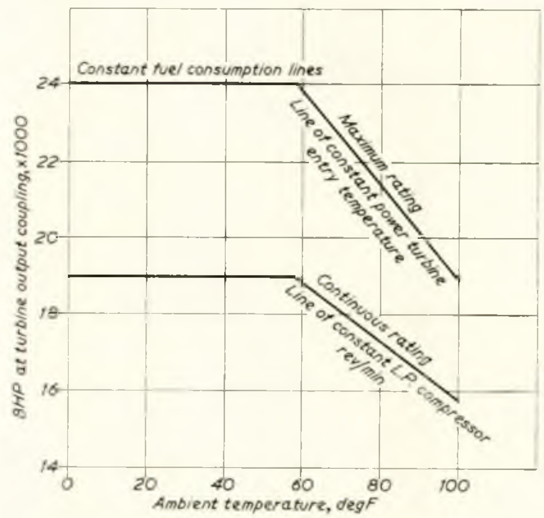
The maximum performance of the marine Olympus engine at an atmospheric temperature of 59° F and pressure of 14·7 lb/in^2, without allowance for ship ducting losses, is as shown in Table I.

TABLE I

	B.h.p.	Specific fuel consumption	Maximum cycle temperature
Maximum rating	24 000	0·505 lb/bhp-h	1155°K
Maximum continuous rating	19 000	0·556 lb/bhp-h	1075°K

All gas turbines have the characteristic that the maximum power available is reduced as the intake temperature increases and the relationship between power and intake temperature for the Olympus engine is shown in Fig. 6.

In addition the thermal efficiency of the engine is at its best at full power and decreases with reduction in power. Fig.



Conditions:—Engine intake pressure, 29·92 inHg abs.
Temperature rise through downtake, nil.
No losses

FIG. 6—*Marine Olympus power unit type TM.1 —Variation of engine bhp with ambient temperature*

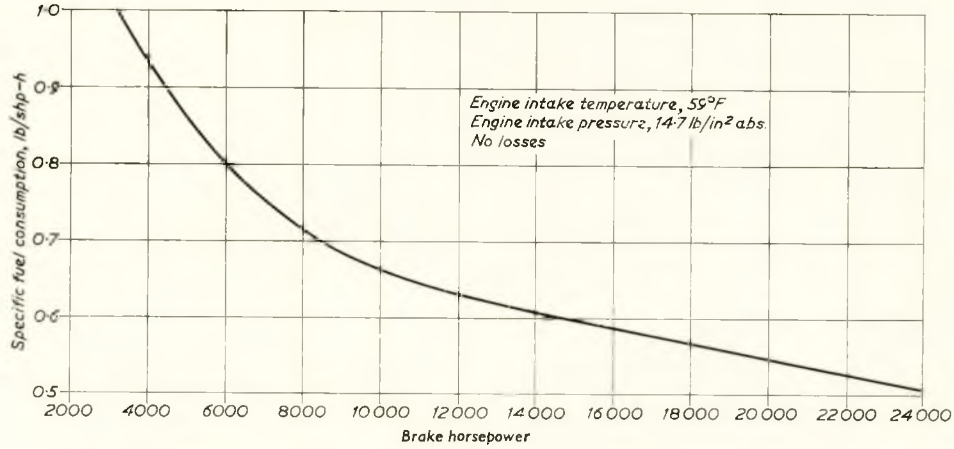


FIG. 7—*Marine Olympus gas turbine—Relationship between engine power and specific fuel consumption*

7 shows the relationship between engine power and specific fuel consumption. It is interesting to note that due to the comparatively high pressure ratio of the Olympus engine, the specific fuel consumption has only increased to 0·63 lb/bhp-h at half power which corresponds to a thermal efficiency of 21 per cent compared with a thermal efficiency of 26 per cent at full power.

As the marine Olympus power turbine is mechanically independent of the gas generator, its output characteristics are such that a wide variation in turbine rev/min is possible at any power setting without serious loss in power or efficiency. The power "map" is shown in Fig. 8.

This attribute is particularly useful if a fixed-pitch propeller is used, as it enables the engine to operate efficiently and without loss in power in circumstances where the hull resistance is abnormal.

The inevitable pressure drops that occur in the intake and exhaust ducting in a ship result in a reduction in engine power and it is quite usual for the intake air to be heated by its passage through the ducting despite the precautions that are taken to avoid this. This involves a further reduction in available power from the engine. Gearbox and transmission losses are also unavoidable and the resulting shaft horsepower available at the propeller is appreciably less than the brake horsepower read off the rating curves.

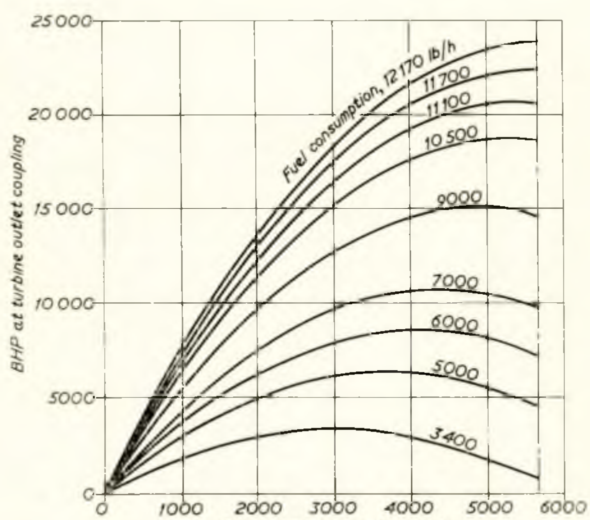


FIG. 8—*Marine Olympus power unit type TM.1—Engine bhp and fuel consumption characteristics*

Great care is taken in any installation to minimize all these losses and it is possible by careful design to limit the total loss of power to about eight to ten per cent of the brake horsepower.

The deterioration in power in service is also a matter of great importance to users of this type of engine. Performance deterioration can be either temporary or permanent, depending on its cause.

Temporary deterioration is almost always due to fouling of the compressor blading by either dirt or salt particles. The ingress of such dirt or salt can be controlled to a very great extent but, even if fouling does occur, adequate means now exist for removing the trouble. The most effective way is by the use of a fine prunus grit known as "Carboblast". This is fed into the intake with the engine running and it cleans the blades by a simple scouring action. Some design precautions have to be taken and careful tests carried out to ensure that the "Carboblast" has no ill effects on other components of the engine but no insuperable problems have been met.

Permanent deterioration can be caused by:

1) erosion of compressor blades;
2) overheating of turbine blades;
3) corrosion of turbine blades.

The erosion of steel compressor blades is not usually a problem at sea, although it can be a very real problem when turbines are operating in sandy and dusty conditions. Adequate intake filtration is the only known preventative.

Overheating of turbine blading can be caused by malfunctioning of the control system or appear as a secondary effect due to some defect in the combustion equipment. In a properly developed engine this is unlikely if the engine is adequately maintained.

Corrosion of turbine blading is a problem usually confined to the high-pressure compressor turbine where the highest gas temperatures are encountered. It is due basically to the effect of sodium salts and sulphur in the gases which can cause intercrystalline corrosion resulting in extreme cases in an appreciable loss of metal from the trailing edges of the blades.

Up to recently this has been one of the most serious problems confronting the designers of marine gas turbines and it has been discussed at length in many papers[1,2,4].

Suffice it to say here that, by the choice of the correct materials and coatings mentioned earlier in this paper and by reducing the salt content of the intake air to below 0·05 ppm, turbine blade corrosion can now be avoided.

With adequate precautions, therefore, and means for simple and effective blade cleaning, performance deterioration need not be a significant factor in engine performance. Two demonstrations of this statement can be quoted, namely, a Proteus marine engine, which showed no performance loss after 4000 hours of testing at the National Gas Turbine

Establishment in a simulated marine environment, and an Olympus 17½ MW generating set, the gas generator of which gave its original test bed performance when retested after running 1100 hours at its full power of 24 500 hp.

INSTALLATION

The main problems of the gas turbine which have to be taken into account in considering ship installations are:

i) it produces a comparatively small power for the amount of air it breathes (about 100 hp per lb air) and therefore large quantities of intake air must be provided and large quantities of hot exhaust gas have to be disposed of;

ii) its power is very sensitive to pressure losses in either its intake or its exhaust system; for example, a pressure loss of one per cent in the intake ducting of a marine Olympus engine would cause a loss in power of 2·2 per cent and an increase of one per cent in the exhaust back pressure would cause a loss in power of 1·2 per cent.

iii) to avoid deterioration of the engine in service the intake air must be free of dirt or salt particles;

iv) its operation gives rise to high noise levels over a wide band of frequencies from the very high frequency noise from the compressor inlet to the low frequency rumble from the exhaust; silencing arrangements have to be made therefore in the intake and possibly the exhaust system and also locally in the engine room itself;

v) its efficiency decreases with decrease in power and below 50 per cent power this deterioration is considerable;

vi) it is a unidirectional engine and some external means of reversing is therefore required.

Fortunately none of these problems is particularly intractable and although it is beyond the scope of the paper to give an exhaustive account of the solutions a brief account of the major design features can be attempted.

Intake and Exhaust Systems

A typical arrangement of an intake and exhaust system is shown diagrammatically in Fig. 9.

Air is taken from as high a point in the ship as practicable to minimize the inclusion of salt spray and passes first through a bank of "Knitmesh" filters. These filters consist of pads of knitted polypropelene through which the air passes preferably in a vertically upwards direction at low velocity. In its passage through the pads the salt water particles are caught by the polypropelene mesh. Filters of this type have proved extraordinarily effective and even in heavy spray conditions the salt content of the air downstream of the pads can be kept down to a figure of about 0·05 ppm which is quite acceptable. The air then passes between sound-absorbing splitter panels into the vertical duct which passes down to the plenum chamber in which the engine intake is situated. The intake duct is kept as straight as possible and has a cross-sectional area sufficient to keep the air velocity at full power down to about 30 ft/s. Normally this air duct is of sufficient size to provide a convenient access passage for the complete gas generator when this has to be removed for overhaul.

Fig. 9 also shows the exhaust duct arrangements. Here again low velocities and freedom from bends are the main requirements. In the illustration the duct is 7ft in diameter resulting in a gas velocity of 200 ft/s. Acoustic treatment of the exhaust duct is shown in this case, but this may not always be necessary.

The considerable space occupied by the inlet and exhaust ducting provides a real problem in the ship's layout and puts a very strict limit on any projected increase in engine size during the life of the ship. It is therefore apparent that any technical development of the engine must be directed towards increasing the engine power without increasing the amount of air needed.

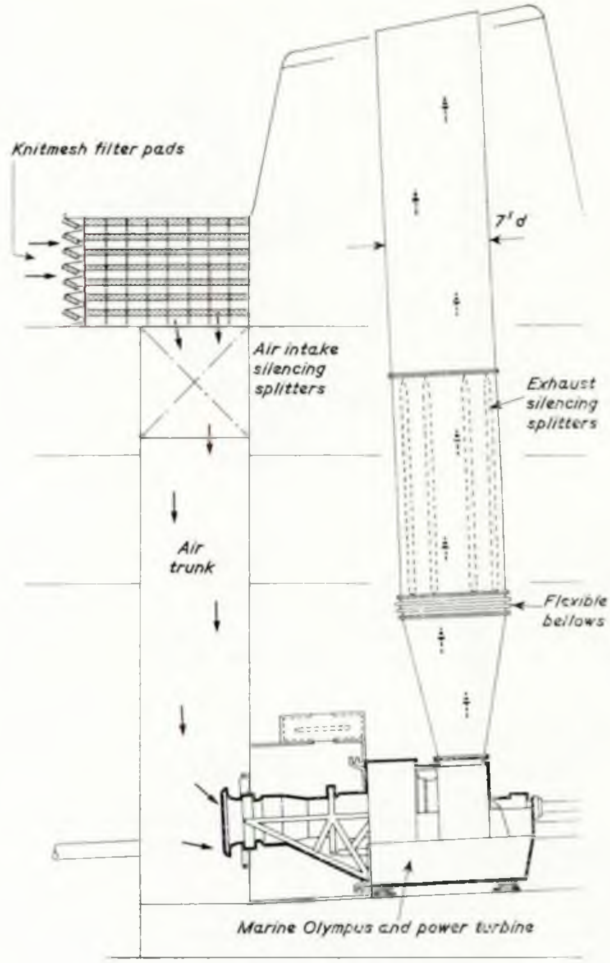


FIG. 9—*Typical intake and exhaust system*

Noise

It is almost a truism that any required degree of silence can be bought. Silencing provisions are therefore always a compromise between the complexity, bulk and cost of the noise suppression arrangements and the acceptability of the resulting noise level. Undoubtedly the intake of a gas turbine of the Olympus type is quite unacceptably noisy by any standards and some acoustic treatment is essential. The exhaust is considerably less noisy but, even here, some treatment is usually deemed necessary. The actual intake and exhaust ducting itself provides a degree of attenuation and a comparatively simple installation of silencing splitter panels in the intake and exhaust usually gives an adequate degree of silencing. For example, in the intake duct described earlier in this section the splitter panels consist of panels 3 in thick spaced at 6 in centres, the panel section being 6 ft long. The panels are basically sandwiches of thin perforated metal sheets enclosing a mineral wool filler. The effect of the silencing system for both intake and exhaust is to reduce the noise level to about that in the passenger compartment of a modern aeroplane. Away from the actual intake and exhaust further attenuation is rapid except for the very lowest frequencies which are not disturbing.

In the engine room itself the bare engine would give rise to an unacceptably high noise level of the order of 110 dB. This can be reduced to a locally acceptable level of some 90 dB by a very simple acoustic hood but, in some installations, requirements exist for further noise reduction and here it would probably be necessary to enclose all the machinery in a complete acoustic enclosure.

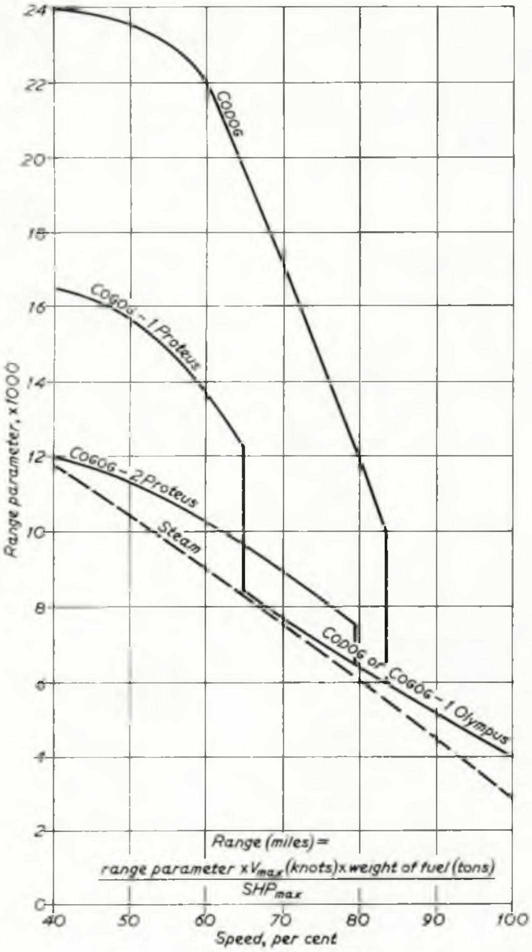


FIG. 10—*Typical range/speed curves for CODOG and COGOG machinery compared with steam turbine machinery in a naval vessel*

Lubrication System

The gas generator of the Olympus TM.1 gas turbine has its own self-contained lubrication system. A synthetic oil to D.Eng. R.D.2487 specification is used for the gas generator and a separate oil tank of approximately 50 gallons capacity is required. The power turbine however needs only a low-pressure supply of mineral oil of the same type used in the main reduction gearing and it is usual to integrate the oil supply for the power turbine with the ship's main gearbox lubrication system.

Multi-engine Installations

The problem posed by the poor efficiencies of the simple gas turbine at low power has to be met by providing separate engines for low-speed and high-speed operation.

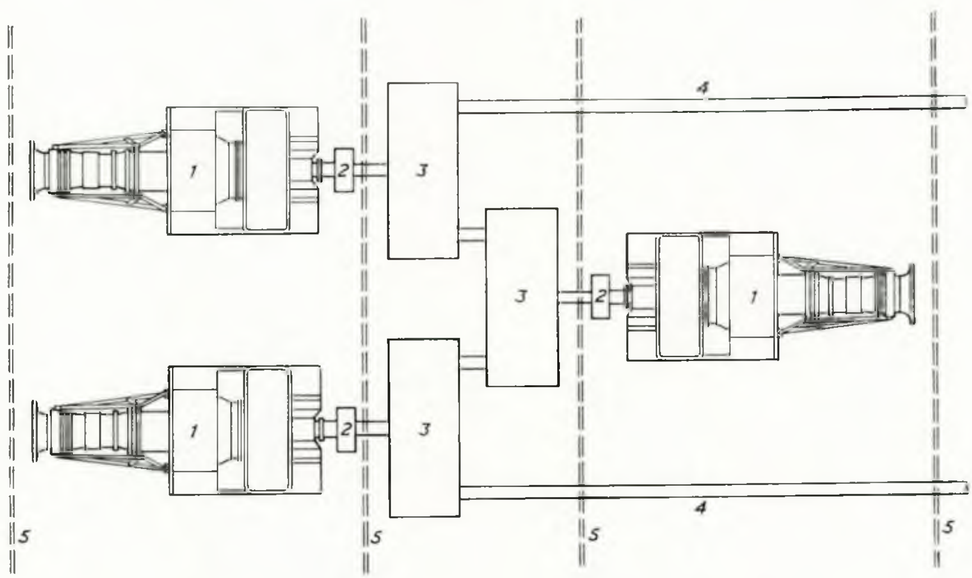
A large number of variants are possible using gas turbines alone or in combination with steam turbines or Diesel engines. The cruising engine or engines may or may not be used when the boost engine is running and so the combined power plant can be either an "and" or an "or" combination. The usual terminology is:

COGAG—Gas turbine and gas turbine,
COGOG—Gas turbine or gas turbine,
COSAG—Gas turbine and steam turbine,
COSOG—Gas turbine or steam turbine,
CODAG—Gas turbine and Diesel engine,
CODOG—Gas turbine or Diesel engine.

The relative sizes of the cruising and boost engines depend very largely on the precise operational requirements of the ship but it is usually found that the best cruising engine size lies between $\frac{1}{5}$ and $\frac{1}{3}$ of the power of the boost engine. Some advantage in maximum speed is gained by the ability to run both sets of engines together—the "and" arrangements—but due to difficulties in matching engine speeds and propeller shaft speeds in the case of the gas turbine/Diesel engine combination, the usual arrangement is to shut down the Diesel engines when the boost engines are being used.

Fig. 10 shows some typical range/speed curves for CODOG and COGOG machinery compared with steam turbine machinery in a naval vessel.

The curves show the advantage in the low-speed cruising range provided by the CODOG arrangement at the present time, but the possibility of more efficient gas turbine cruising engines in the not too distant future together with the opera-



1) Olympus gas turbine
2) Clutch
3) Gearbox
4) Propeller shaft
5) Bulkhead

FIG. 11—*Arrangement of two-shaft ship using three marine Olympus engines*

tional advantages of an all gas-turbine design leads the author to believe that the all gas-turbine ship will be the future trend in vessels requiring up to 100 000 shp.

The interesting principle of using "half" gas turbines is worth discussing in this context. An arrangement of a two-shaft ship using three marine Olympus engines is shown diagrammatically in Fig. 11. The power from any or all of the three Olympus engines can be divided between the two propeller shafts by means of arranging a clutch between each of the engines and the transmission gearboxes. This arrangement will thus allow the power of 1½, 1 or ½ engine to be provided on each shaft and thus affords the possibility of covering a power range from full power down to 17 per cent power without having to reduce the power of any one engine below 50 per cent. The effect of this on the range/speed relationship compared with the more conventional combination of a marine Olympus boat engine and a small cruising engine of 6000 hp is shown in Fig. 12. For the sake of the comparison the smaller cruising engine is assumed to have the same efficiency characteristics as the Olympus.

The three-engine arrangement has the operational advantage of only using one type of gas turbine in the ship and, since any two of the engines are capable of driving the ship at about 90 per cent of its maximum speed and any one of the engines at 75 per cent. of its maximum speed, also provides an excellent degree of reliability.

The part played by the main gearboxes in these installations in providing speed reduction, clutching arrangements for different engine combinations and in ordinary cases the reversing function is obviously of vital importance. The successful development of suitable gearboxes has been a major factor in the use of gas turbines in ships and we have been fortunate in

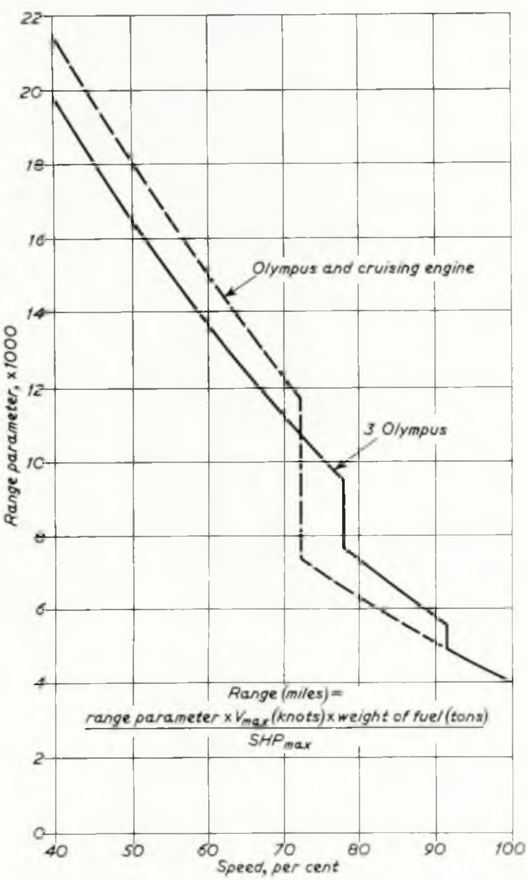


FIG. 12—*Range/speed curves for a two-shaft ship using three marine Olympus engines compared with single Olympus and a 6000 hp cruising engine*

this country in having both the design and manufacturing skills available and the wholehearted support of the Ministry of Defence (Navy) over the past years in solving the problems involved. Accounts of the gearbox design and development have been given in a number of important papers[3, 5] and will not be discussed here.

Engine mounting systems to avoid trouble due to shock, to insulate the hull from vibration noise from the prime mover and to maintain engine/gearbox alignment in all circumstances form another specialized subject. Apart from the design features of the Olympus gas turbine which have been specially provided to ease the mounting problems and which have been described earlier in the paper, no detailed account of the many engine mounting systems will be attempted.

Plans for installing the Olympus gas turbine are already well advanced for a number of naval vessels and provide examples of the all gas-turbine installations, gas turbines and Diesel engines and gas turbines and steam engines. Illustrations of two such installations make a suitable conclusion to this section.

Fig. 13 shows the engine room layout of H.M.S. *Exmouth*, a *Blackwood* Class frigate, which is now being converted from steam turbine to all gas-turbine propulsion. Two Proteus engines of 3400 hp are used as cruising engines and a Marine Olympus TM.1 engine for boost.

Fig. 14 is a picture of the engine arrangement in the Yarrow frigate which is being built for the Royal Malaysian Navy. Here a central gearbox takes the power from a marine Olympus TM.1 engine forward of the gearbox and a Pielstick Diesel engine aft of the gearbox. The gearbox has two output shafts driving two controllable-pitch propellers and is the first example of the principle of using "half" gas turbines.

A complete marine Olympus TM.1 engine is now undergoing extensive shore trials under the auspices of the Ministry of Defence (Navy) in a test bed at Ansty. The installation is complete up to the ship's gearbox input flange and includes a set of the actual ship's engine control gear and consoles. Testing commenced at the beginning of August 1966 and will provide valuable operating experience before actual operation at sea can begin.

FUTURE DEVELOPMENTS

The use of the simple-cycle gas turbine based on the aero engine or aero engine technology is only in its infancy. The widespead and growing acceptance of the marine Olympus and similar engines is merely a starting point and firm possibilities already exist for major improvements in the performance, reliability and installational advantages of this type of engine.

The marine Olympus TM.1 engine has a compression ratio of 10 : 1 and can operate at a maximum cycle temperature of about 1160° K [887° C (1629° F)]. This results in a thermal efficiency of about 26 per cent and a specific power slightly in excess of 100 hp/lb air/s. Established aero gas turbines already operate at much higher cycle temperatures by adopting turbine-blade cooling techniques and, by combining higher cycle temperatures with higher compression ratios, substantial improvements both in thermal efficiency and specific power can be obtained.

The full lines in Fig. 15 show the estimated performances possible over a range of maximum cycle temperatures up to 1500° K [1227°C (2241° F)] in combination with the corresponding optimum compression ratios.

A degree of turbine-blade cooling which is very modest by aero standards will allow the maximum cycle temperature to be increased to 1300° K [1027° C (1881° F)] which would raise the thermal efficiency to over 30 per cent and the specific power by over 30 per cent. Such a step would present no new technical problems and action has already been taken to provide engines of this type by the early 1970s. Research work leads one to believe that the figure of 1500°K [1227° C (2241° F)] for maximum cycle temperature is by no means unattainable and that compressor designs suitable for compression ratios of over 20 : 1 are quite practicable. Thus in the future the

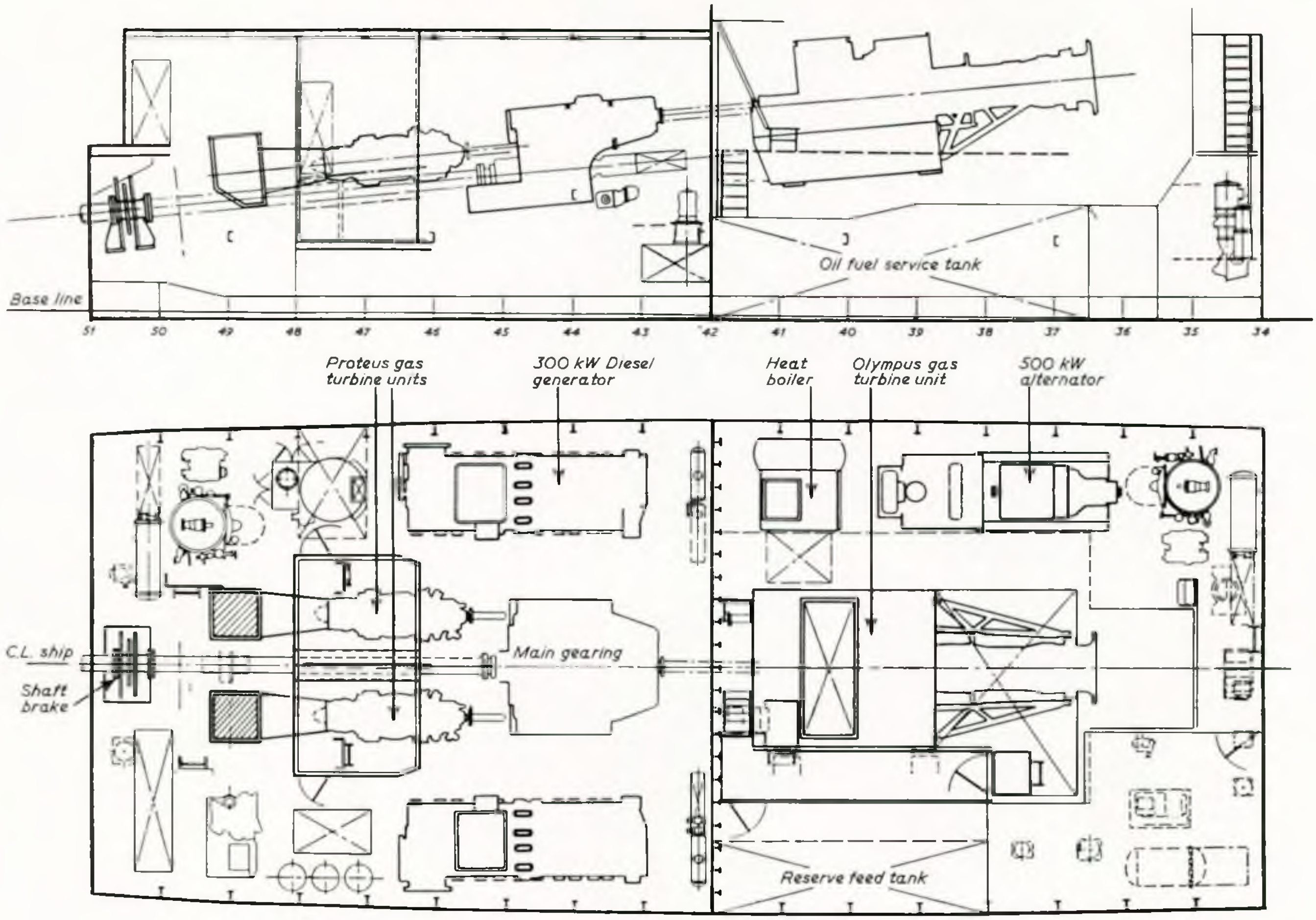


FIG. 13—*Engine-room layout of H.M.S.* Exmouth

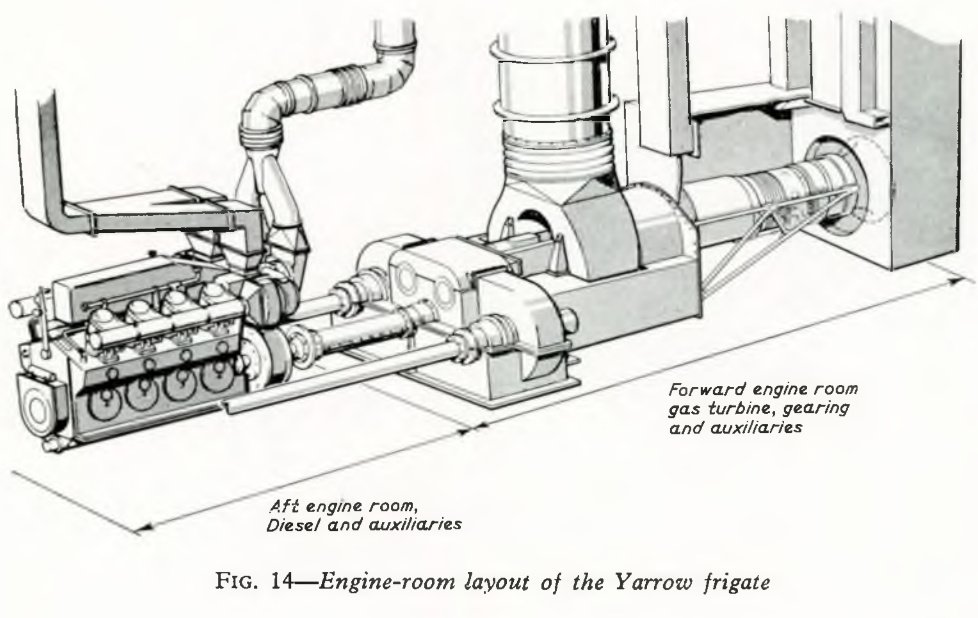


FIG. 14—*Engine-room layout of the Yarrow frigate*

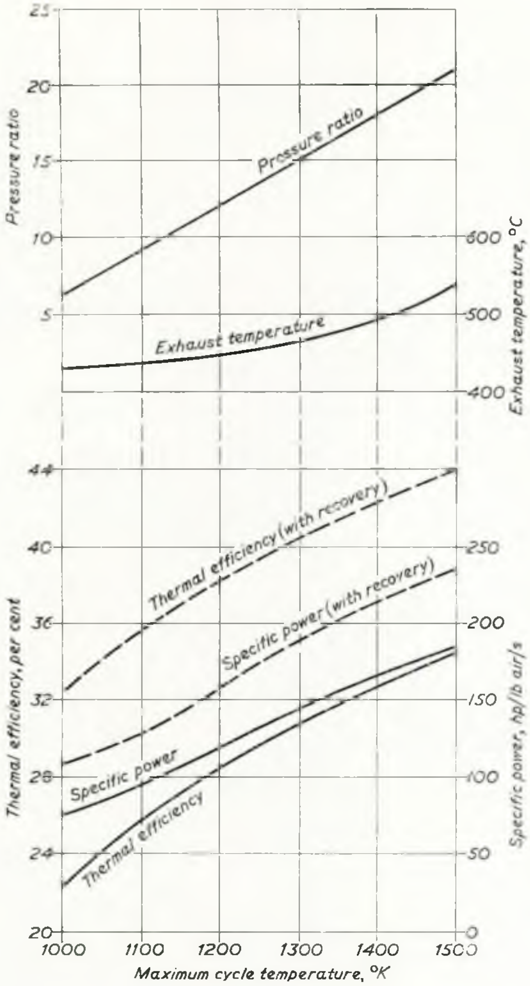


FIG. 15—*Generalized performance characteristics for a range of gas turbine engines with and without exhaust heat recovery*

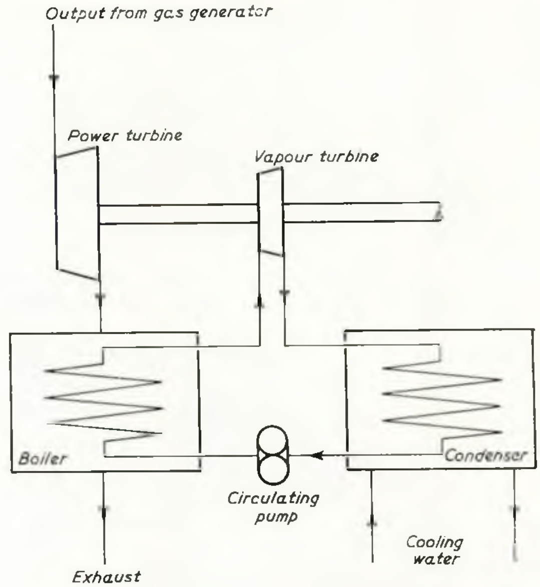


FIG. 16—*Diagram of Arcton 21 cycle*

simple-cycle engine will be able to provide 175 hp/lb air/s with a thermal efficiency of some 34 per cent.

Fig. 15 also shows that over this range of maximum cycle temperatures the engine exhaust temperature rises from about 430° C (806° F) to 530° C (986° F) despite the increase in thermal efficiency and so the possibility of utilizing the exhaust heat tends to increase.

The exhaust heat can be used either for providing extra engine power or for other essential services such as refrigeration, distillation or other domestic services. Usually the balance of requirements is such that it would be advantageous to convert a considerable proportion of the exhaust heat into power if this was possible. The use of the heat in a steam boiler is an obvious possibility, but studies show the resulting low pressure steam turbine to be bulky and unattractive. Intensive studies have however recently been carried out in connexion with land installations of the use of one of the modern refrigerants such

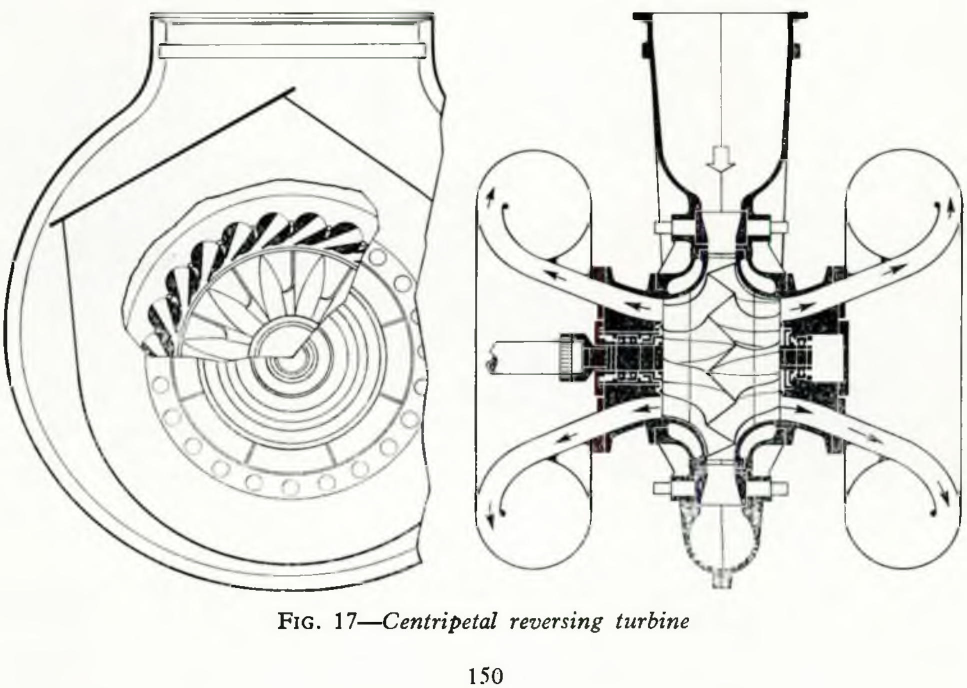


FIG. 17—*Centripetal reversing turbine*

as Arcton 21 as a working fluid. The thermodynamic properties of this type of fluid make it possible to do the expansion work in a single turbine stage and its chemical properties are well suited to the temperature range necessary. Fig. 16 shows a diagram of the cycle used.

Referring to Fig. 15, the very remarkable improvement in both thermal efficiency and specific power which results from an exhaust heat recovery system of this type can be seen. At the maximum cycle temperature of 1500° K [1227° C (2241° F)] a thermal efficiency of 44 per cent is predicted with a specific power of 235 hp/lb air/s—more than twice that of the Olympus of today and comparable with Diesel engine figures.

Even at a top temperature of 1300° K [1027° C (1881°F)] which will shortly be possible in actual engines the thermal efficiency would be just better than 40 per cent.

These advantages are of course offset by the considerable additional cost and bulk of the necessary boilers and condensers and the corresponding additional complexity of the installation. The important feature is, however, that such additions to the simple-cycle engine do not in any way affect the engine itself and its development. A choice can therefore always be made by the ship's designers whether or not exhaust heat recovery is desirable for any particular specification.

Enough has been said in this very brief review of future possibilities to show that unlike most existing marine engine types the simple-cycle gas turbine engine is capable of vast improvement in its present performance.

Again in the installation aspect improvements are being studied. Engine-room space could be saved if the gas generator could be installed vertically in its own air-intake duct. Only minor modification to the bearing oil scavenge arrangements are necessary to achieve this, but the full advantage could not be obtained without a complete redesign of the power-turbine section of the engine.

The provision of direct reversing is a problem that is receiving serious study. The avoidance of reversing gearboxes with the necessary clutches and controls while retaining the fixed-pitch propeller, is a prize worth attempting. As engine-power requirements increase this aspect will become of ever increasing importance and already some progress has been made.

Fig. 17 shows the design of a centripetal reversing turbine which has recently been tested at the author's works. It is in fact a one-third scale model of a 9000 hp power turbine which would be required to give at least 3000 hp astern. The nozzle blades consist of a ring of discrete nozzles which can be rotated in unison from the ahead to the astern direction. During this manœuvre the effective nozzle size is unaltered and so the gas-generator controls need not be affected. Tests have shown that the overall efficiency in the "ahead" direction was nearly adequate in the first design while the "astern" efficiency was more than adequate and would correspond in effect to having 60 per cent astern power available rather than the 33 per cent required.

The final turbine would be installed as indicated in Fig. 18. A marine Olympus gas generator mounted vertically in its intake duct would provide gas to two centripetal reversing turbines coupled by gearing and clutches into the port and starboard propeller shafts. A ship would have a number of such installations each in its own engine room. The engine rooms would be very short and separated from each other by athwartship bulkheads. Any number of engines from one to the maximum installed would be used as appropriate to the ship's speed requirements, thus obtaining minimum operational fuel consumption.

The basic problem with this system however is the size of turbine rotor necessary for a given power. The maximum forging weights available limit the size of an individual turbine to some 10 000 hp at the present and in any case the specific size and weight of such power turbines is very inferior to existing axial turbines.

The search for the ideal reversing turbine therefore must still continue.

A final note may be added on the subject of engine reliability. The power turbine section of the marine gas turbine engine is a very simple expansion turbine working well within known limits of its component materials. With the aero engine background of design data on aerodynamics, materials and stresses, both steady and vibratory, and the knowledge of both long and short term fatigue problems, there is no doubt that the marine power turbine will be a reliable long-life component.

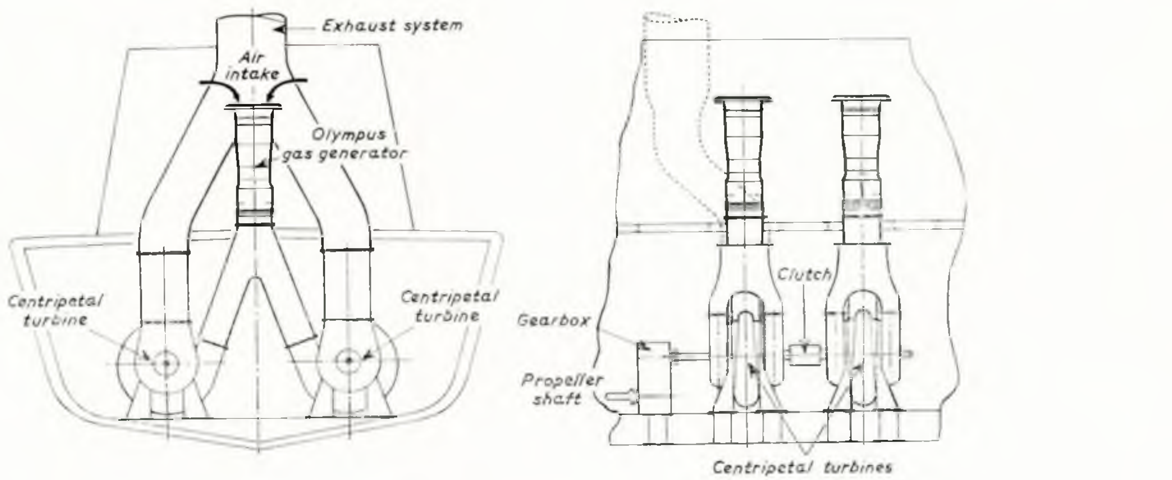


FIG. 18—*Installation of centripetal turbine*

While it is an essential part of the overall plan that the gas generator will have a limited life, the vast amount of aero engine experience in the gas-turbine field has demonstrated beyond doubt that this "life" is predictable. The actual time between overhaul of the gas generator will depend on the ratings at which the engine is used and the choice of ratings, and therefore mean time between overhauls will be chosen to meet the requirements of any particular vessel. It must be realized that the high ratings mentioned will be obtained without any reduction in the "life" margin of any of the components in the engine. For example, blade cooling for the high cycle temperatures will keep the actual blade material temperature down to its previous value unless material changes allow the temperature to be safely increased.

The ability to predict accurately the required time between overhauls and the repair by replacement of the gas generator offers the prospect of better ship availability and reduced on-board maintenance charges. The suitability of this type of engine for operation by remote control offers further opportunity for reduced operating costs.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to Bristol Siddeley Engines Limited for their permission to write this paper and to the Ministry of Defence (Navy), Yarrow and Co. Limited, Brown, Boveri et Cie and the Central Electricity Generating Board for permission to use material contained in the paper. The diagram in Fig. 13—Engine-room Layout of H.M.S. *Exmouth* — is reproduced with the permission of *Engineering*. His special thanks are due to a number of his colleagues at Bristol Siddeley Engines Limited for their personal efforts in the preparation of the paper and its illustrations.

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5) Weaving, P. D. V., and Sampson, W. H. 1963. "Progress and Development in Naval Propulsion Gears 1946-1962". *Trans.I.Mar.E.*, Vol. 75, p.121.

Discussion

Commander E. B. Good, R.N. (Member) said that the author mentioned the important point—as far as warship operation was concerned—of exhaust smoke, and quoted C.E.G.B. operational experience with gas generators, for electric generation, all predominantly at full power. It was equally important to ensure that the exhaust was clean throughout the power range. Even in this day of sophisticated radar it was inadvisable to give away the ship's position by a smoke plume, at any operational speed. Were smoke results available for the full Olympus operating range?

The author had stated that the power turbine for TM.1 and 2 was a single-stage turbine. Could he enlarge on his reasons for using only one stage? The Brown, Boveri power turbine he mentioned used two stages and machines of a similar power, by overseas competitors, also employed two stages and made considerable capital out of having a better power turbine efficiency.

On intake and exhaust systems, the author made the point that the "Knitmesh" filters should be placed horizontally so that the air passed in an upward direction at low velocity. Commander Good's understanding was that the pad should not be truly horizontal, as this had quite the reverse effect and under those conditions the water was more often than not ultimately entrained with the air flow. The pads needed to be angled, as shown in Fig. 9 so that the water drained downwards across the pad face, was trapped at one edge and led away in suitably constructed gutters.

The whole question, however, of intake and exhaust systems was far more important than this minor point and he would enlarge on the implications which the systems had on the overall ship design. Hitherto, in the more conventional Diesel and steam turbine installations, the naval constructor had customarily dictated the funnel and uptake location, from the viewpoint of ship arrangement only. The advent of marine gas turbines, which required, in comparison, very high air/fuel ratios, necessitated the closest collaboration between the naval constructor and the marine engineer for the best overall ship design to be achieved. If full advantage of this new prime mover were to be taken then these could not be fitted as an afterthought or as a substitution in a ship originally designed for steam machinery. To reap the full benefits of a "repair by replacement" policy, the integration of the gas turbine downtakes into the ship arrangement must be made at a very early stage in the overall concept. Straight runs on both the exhaust and intake side were fundamental and the bending of uptakes, to suit configurations above the machinery deck, should be discouraged.

Experience had shown that, providing these requirements were taken into account by the naval constructor immediately the ship design was conceived, then it was possible to lay out the compartments, in way of the machinery uptakes, without prejudice to the compartmentation as a whole. However, in cases where preconceived arrangements had been arrived at without due consideration to the implications of these larger ducts and intakes, compromise solutions were often reached which were bound to be deprecated by operational engineers who would later have to "steam the ship".

Fig. 10 presented an interesting range/speed curve for various types of gas turbine combined machinery. It was difficult to comment, in the absence of details, as to the basis on which the curves were drawn, but he found the relative value between the Codog/Cogog and steam installation interesting, as it did not appear to line up with the figures already published in his own paper*. From Fig. 19 it could be seen that a Codog installation, at the lower end of the speed range (12 knots) was more than two and a half times as effective as a steam installation. Moreover, the ratio in endurance between such a Codog installation and a Cogog using one Proteus was nearer 2·0 rather than the 1·5 shown in Fig. 10.

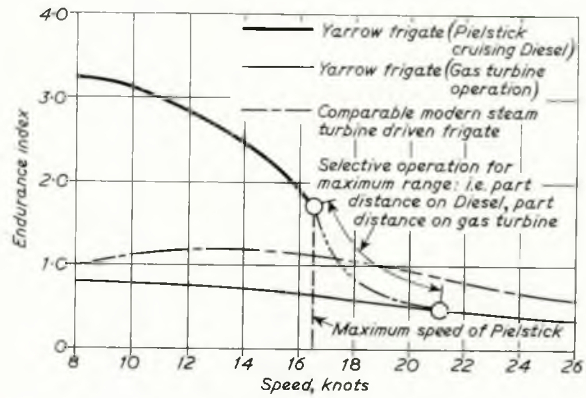


Fig. 19—*Endurance comparison*

A significant problem arising with combined machinery installations, which were much in vogue with many navies for frigate and destroyer propulsion, concerned the selection of the cruising prime mover. The original impetus for the change to gas turbine propulsion had come from the Royal Navy and originated from two main fields, boost gas turbines and fast patrol boats. Each of these fields had an important common factor—the gas turbine was used for relatively short periods at its peak rating. The cruising engine's operational mode differed fundamentally from the boost engine in that it was called upon to operate at or close to its maximum rating continuously and it required long life for sustained cruising periods at high powers.

It was useless for design engineers to argue that the engine would be designed and installed to run safely at below its maximum rating. The operators of ships would inevitably override this limitation in the heat of action and call for the maximum available power, and junior engineer officers would comply with their Captain's wishes. He believed that very careful thought needed to be given to the wisdom of selecting gas turbines as cruising engines. Fortunately in the case of Proteus there was a long and well-established background of sea experience, such as was not the case with other engines which had been put forward as cruise units. He contended that in many respects the selection of the cruising engine in a combined plant was more vital than that of the boost engine. It was this engine which would carry the ship through its

*Good, E. B. 1966. "Gas Turbine Installation for Naval Ships". Paper presented to A.S.M.E. in April.

operational life. A combined plant was complex, involving as it did two dissimilar prime movers, and gave rise to logistic and training problems. If this complexity was to be justified, the order of the gains achieved must correspondingly be large.

He had some doubts whether the improvements in endurance occasioned by the use of cruising gas turbines were sufficiently attractive to warrant this complexity. On the other hand, the use of Diesels in a CODOG offered significant improvements in operational endurance. Obviously each warship installation needed to be analysed on its own merits and no hard-and-fast rule could be laid down, but one general point was certain—the worst possible procedure for a new class of warship was to insert a gas turbine installation into an existing ship design previously evolved for a steam machinery installation.

The doubts expressed about cruising engines clearly did not apply to the 3 Olympus arrangement, shown in Fig. 11 and described on page 148, which he had always considered to be a most attractive concept. Unfortunately, the gearbox shown was rather easier to draw diagrammatically than it was to design in detail, and considerable design effort and study would be necessary to produce a practical and viable machinery installation design.

There were some minor corrections to some detailed figures stated in the paper. These were:

a) Table I and Fig. 7 were inconsistent as the first was in brake horsepower while the second quoted shaft horsepower and said no losses had been allowed;

b) on page 146 the intake duct velocity of 30 ft a second should, as far as Y-A.R.D. installation designs were concerned, be of the order of 80 ft a second.

The Royal Navy had very wisely taken the precaution of putting to sea one experimental COGOG installation at minimum cost, the H.M.S. *Exmouth* conversion. The sea experience of this ship would be eagerly awaited by all marine design engineers.

CAPTAIN D. G. SATOW, R.N. (Associate Member) said that, the interest of the Royal Navy and many other navies in aircraft gas turbines for marine use in particular the Olympus, was widely known and it might be worth while briefly to reiterate the reasons which had led to this interest.

The Navy was currently powered predominantly by steam turbo-machinery, but which had been developed very nearly to its logical conclusion, in the opinion of many people. Indeed, some might say that it had been developed in some ways to its illogical conclusion. This implied no criticism, because it was designed to meet the extraordinarily difficult and demanding requirements of the Navy. It was something of a triumph that these had been met so well. However, these stringencies had led to machinery-installation characteristics which could no longer adequately match the needs of the future. Neither the reliability nor the availability, which were needed, were being achieved. Maintenance was much higher than could be afforded and was aggravated by complexities, which resulted from efforts to save weight and space and, in particular, from the many auxiliary and associated systems inherent in this type of machinery. In addition, automatic controls had recently appeared and, despite their merits, had added to the problems. Finally, accessibility was a major difficulty.

For the future, the important characteristics sought were: first and foremost, reliability. This needed no clarification; it was perhaps too much to talk about absolute reliability, but reliability of a very high order was sought.

Second, was availability. The use of Her Majesty's Ships was constantly rising and this was probably an inescapable trend. This implied, in addition to reliability, that ships were required to spend less time in harbour under maintenance.

Third, was the ability to overhaul by replacement. If ships were to spend less time in harbour under maintenance, turn-round must be speeded up by reducing the on-board maintenance where possible and, in particular by being able to remove engines rapidly, for overhaul ashore, reconditioned engines being replaced at once.

The fourth requirement concerned manpower. The Royal Navy, too, faced difficulties with technical manpower and the requirements for operation and maintenance must be minimized.

The fifth requirement dealt with cost, always a vital factor. Although first-cost was no less important than it had been, there was a growing tendency to attach increasing importance to overall through costing. The great difficulty was to try to quantify this and to show that an increase in first-cost could often result in great savings on maintenance or other through-costing aspects.

These factors were all interrelated and there were many other requirements. Prolonged study had been given to all these matters and the general conclusion had emerged that basic requirements could be achieved only by the use of the Olympus-type engine. This gave a fully-packaged power plant which in relative terms was of great simplicity and therein lay its basic attraction for naval use.

There was also a number of other advantages for naval applications, e.g. the standardization of power plants which produced savings in logistics, training and so on.

There were some disadvantages, too, and many problems in the application of this type of engine to naval ships. He emphasized that although there were many areas of similarity between the power plant of the Merchant and Royal Navies, there were great differences in the factors influencing their design. As a small indication of how different they could be, the shaft horsepower of a 200 000-ton tanker was of the same order as that on each of the two shafts of the *County* Class G.M. destroyers, of 6000 tons. It might be difficult to find much else in common, but to be a little provocative, perhaps someone might like to comment on what two Olympus engines would look like in a big tanker.

It was a little over 20 years since Sir Frank Whittle had delivered his historic James Clayton lecture to the Institution of Mechanical Engineers, outlining his pioneer developments of the gas turbine. He had concluded with the following sentence,

> "The use of the gas turbine will not, of course, be confined to aircraft. I expect to see it reach some prominence in the field of marine propulsion."

The Royal Navy had pursued the application of the gas turbine at sea ever since and was now on the threshold, Captain Satow believed, of this prediction assuming some reality. The author had been generous enough in his introduction to recognize the part played by the Navy's engineers in this development. It would be ungenerous not to reply that the author and his organization had taken the trouble to study the problems of applying aero gas turbines at sea, and to understand the user's requirements and what, at times, might appear to be his peculiar whims but which were occasionally the product of long and hard found experience.

MR. J. H. MILTON (Member) said that the gas turbine was a power unit with which most marine engineers, including himself, had little experience.

He had attended the sea trials of a gas-turbine merchant vessel, the *Morar*, but in this case the gas for the turbines was produced by gasifiers. One interesting point of this installation was the light construction of the turbine and, rightly or wrongly, he could only assume that this was accounted for by the enormous throughput of comparatively low pressure gas which enabled the power to be developed. An interesting comparison between the throughput of gas in a gas turbine installation and steam in a conventional steam-turbine installation could be assessed from the figure quoted in the paper, 100 hp/lb of air/s, compared with 600 hp/lb of steam/s for the steam turbine.

There was a number of points about the Olympus gas turbine on which further information would be appreciated. First, the author gave the impression that the marine Olympus had been designed specifically for high-performance naval craft. Had he envisaged its use in the Merchant Service and had the economics of such an application been studied? Apparently the undoubted advantages of the aircraft gas turbine, when adapted for marine work, had to be bought. In naval applications real advantages had to be obtained irrespective of cost.

For Merchant Service use, the advantages in relation to conventional machinery seemed to be outweighed by the additional overall cost of operation.

Even allowing for the outlined projected increase in the thermal efficiency of the gas turbine, to compare favourably with the Diesel engine, the problem of fuel cost would still remain. Thus, the gas turbine would not become competitive in merchant marine applications until use could be made of the vastly cheaper residual fuels. If the use of such cheaper fuels became possible in the future, what were the penalties likely to be incurred and how could they be overcome?

Secondly, on page 144, projected figures of 3000 and 6000 hours between overhauls were quoted for gas generators on boost and cruising conditions respectively. It was usual for present-day tankers to be at sea for a minimum of 300 days, or 7200 hours, yearly. Was it envisaged that the future gas-turbine merchant vessel would have several de-rated Olympus units and that, on a rota, each one would be changed at yearly intervals? Furthermore, could the author quote a rough figure for the cost of the repair by replacement for one gas generator?

Thirdly, the gas generator employed two mechanically independent axial-flow compressors driven by separate axial-flow turbines. The low-pressure compressor was driven by the low-pressure turbine and the high-pressure compressor by the high-pressure turbine, and as all were co-axial this necessitated the L.P. turbine driving through the shaft of the H.P. turbine.

That this had been accomplished with thrusts and couplings on both of these independent units was an outstanding example of engineering skill. What were the reasons for splitting the gas generator into two independent units, as there did not appear to be interstage cooling applied between the compressors? Was this done for aeronautical reasons; for marine purposes—where size and weight were not of such paramount importance—could not a similar but relatively simpler result have been obtained by combining the two compressors into one unit and the two turbines into another?

Fourthly, the average superintendent engineer would most likely accept a power turbine with an infinite life, but he might have second thoughts on a gas generator which, apart from having a short specified life between overhauls, would need frequent washing through. How frequent was such cleaning likely to be needed and could it be accomplished under normal operating conditions?

Commander W. J. R. Thomas, R.N. (Member) said that Fig. 10 showed the Diesel engine to great advantage and Commander Good, too, had commented on the great advantage of the Diesel engine. It would be wise to emphasize that this was so for particular cases only and was not necessarily true for all naval vessels. One parameter of particular importance to the machinery project engineer was the machinery plus fuel weight needed to meet the Naval Staff requirements of endurance and speed. As the speeds of merchant ships rose, so the naval cruising speeds rose to match them. Because the required shaft horsepower rose roughly as the cube of the ships speed, the necessarily high cruising power requirements for medium to large warships resulted in very bulky Diesel engines and, hence, difficulty in fitting them into the machinery spaces. When their weight was subtracted from the allowable machinery plus fuel weight, the weight left for fuel might in some cases make the endurance obtainable from the cruising Diesels less than would have been obtained with the lighter all gas turbine installation. In one particular case which had recently been considered by the Ministry of Defence (Navy), the endurance at the required cruising speed fell to one quarter of what it had been with gas turbines, if these were replaced by Diesels for cruising.

This might seem surprising, in view of the markedly better specific fuel consumption of the Diesel engine. Obviously, there was a change-over point, hinging upon the cruising power needed and the allowable machinery plus fuel weight; it was not a foregone conclusion that the Diesel engine was always best for cruising.

The author made no mention of the difficulties involved in CODAG and COGAG arrangements. In the former, two-speed gearing might be necessary to allow the powers of the two engines to be added: in the latter one could use two-speed gearboxes, or allow one turbine to overspeed as the other was clutched in, if two turbines of different powers were to be added. Both proposals involved complications, but something of the kind was essential if the powers were to be added while maintaining reasonable specific fuel consumptions from both the engines. Not the least of the important advantages of all gas turbine installations in naval vessels was their simplicity, although this might not be so valid in merchant vessels. Naval vessels needed very large power plants, in very small spaces, and had to be arranged to cope with action damage. Simplicity was a very important quality when the lights went out and he felt strongly that complication should be avoided unless there were overriding reasons for its adoption. He thought that they were in a strong position at the moment, in that not only had the best gas turbines better specific fuel consumptions than those of the best naval steam plants, but those specific fuel consumptions were likely to improve. They could therefore afford to be just a little complacent, not scratching too hard for efficiency at the expense of simplicity.

He had been intrigued by Commander Good's comment that the engineer must not allow the naval architect to dictate what went on above the machinery spaces. Apparently Commander Good had his naval architects better trained than had Commander Thomas. He had recently been faced with the problem of how to get the engines under the funnels in a recent design. Such was the conglomeration of bits and pieces which must appear on the topsides of naval vessels today that this became a necessity and, in this instance, the problems of the naval architect were far worse than his own.

Mr. M. K. Forbes said that a point had been made in the paper that the aircraft engine and, in particular, the gas turbine, was both light and very compact in comparison with conventional marine propulsion units. These two aspects were of vital importance in aircraft applications and much of the intense development applied to aircraft engines had been aimed at reducing the weight and size of an engine for a given power output. The same was true of auxiliary equipment used on these engines.

It would, perhaps, be interesting to compare the relative size and weight of a particular auxiliary equipment used on the Bristol Olympus 200 series aircraft engine with the equivalent equipment for a marine steam turbine producing roughly the same power output. In the aircraft engine, the oil cooler, using fuel as the coolant, weighed 33 lb, whilst for cooling the lubricating oil for the equivalent steam turbine, a cooler weighing 11 300 lb was required, in which the coolant was sea water. The relative volumes of the two coolers were in the ratio of about 1 to 75.

It was possible to discover the principal reasons for these marked differences in size and weight of the coolers by considering their different constructions and operating conditions. The aircraft cooler, manufactured entirely from aluminium alloys, employed tubes with an outside diameter of less than ¼ in, the small bore being possible because the tubes handled only filtered fuel. On the other hand, the marine water-cooled oil cooler contained copper alloy tubes with a bore of about ½ in, to avoid clogging by débris entrained in the sea water, and most of the remaining components of the cooler were of cast iron.

The required rate of heat removal from the lubricating oil in the aircraft engine was about one-hundredth that in the steam turbine, whereas the temperature difference between oil and coolant in the two cases was in the ratio of about 3 to 1 (see Table II). Both these factors had a profound influence on

TABLE II

	Gas generator: oil cooler Olympus	Steam Turbine oil cooler
Oil grade	D.E.R.D. 2487 (synthetic)	O.M. 88 (mineral)
Heat to oil: Chu/h	15 300	1 480 000
Maximum oil temperature °C (to turbine)	70	45
Coolant	BS.2869 Class A Diesel fuel	Sea water
Maximum coolant temperature °C	35	32
Fluid temperature difference °C	35	13

cooler size. The higher operating temperature in the aircraft engine was made possible by the use of synthetic oil. It was only the excellent heat transfer properties of water that saved the sea-water cooled unit from being several times larger.

In the marinized version of the Olympus engine, the same fuel-cooled oil cooler as in the aircraft engine was employed for the gas generator, but a separate sea-water cooled unit was required for the power turbine lubricating oil system. This cooler, built to marine requirements, was in the order of one-third the size and weight of the cooler for the steam-turbine installation.

COMMANDER A. J. R. SMITH, R.N. said that Commander Good had anticipated many of his questions about the combustion equipment changes. He would, however, add to the list of items which necessitated a ship carefully controlling smoke an important consideration from the naval aspect, i.e. that a carrier would be conducting helicopter operations close to the ship, quite often; the emission of smoke in those circumstances was a grave embarrassment to the operational efficiency of the aircraft.

With reference to shock, at the Ministry of Defence (Navy) it was believed that the novel mounting design evolved for the Olympus (see Figs. 2 and 3) would enable it satisfactorily to meet any shock loading likely to be encountered in war service at sea. The integrity of the machine under those conditions would fully measure up to that of machinery of different types now fitted in the Fleet. It was the intention to subject the prototype engine to a practical trial in the future.

Under the heading "Performance", 6000 hours time between overhauls was referred to as being a reasonable figure for cruising engines. Did the author feel that this figure would apply to the engines shown in Fig. 11, some or all of which must be regarded as cruising engines? If so, upon what rating was the time between overhauls based?

On time between overhauls generally, there had been a dramatic increase over the last 20 years. In the case of aero engines it had been tenfold or more. It appeared to be common practice to put an engine into service initially with a fairly short time between overhauls and then to extend this time following the results of examination and detailed modifications through engines put in for overhaul. He hoped that this procedure would apply to the marine Olympus; was the author prepared to indicate how far and how soon he believed that time between overhauls for this engine, operating at the quoted rating, would be extended?

In Table I there was a reference to maximum ratings and performance figures about which there was often a tendency to confusion. No discussion of time between overhauls or power inputs to the main gearing was meaningful unless maximum cycle temperatures and operating cycles were specified, together with ambient conditions and ducting losses. In the naval context, the time between overhauls was normally given on the assumption that 5 per cent of the engine's life was spent at maximum rating and the remaining 95 per cent at or below continuous rating, which was 80 per cent of full power. This was entirely consistent with the operating pattern for engines in service in both main propulsion and electrical generating roles.

The effect of ambient temperature was shown in Fig. 6. Under tropical conditions, a power loss of about 20 per cent of the maximum rating must be accepted, unless extreme emergency dictated that the maximum cycle temperature was exceeded. In this case, however, an exchange of gas generator must be made as soon as possible after the emergency had been overcome. The power reduction because of the limited cycle temperature was reflected in the increased specific fuel consumption in the proportion indicated in Fig. 7.

When considering the installed horsepower, ducting losses must be taken into account; the author had quoted figures for these. These reflected on the specific fuel consumption in the same way as did temperature variations.

The protective measures to deal with salt corrosion described in the paper represented what the Navy currently thought to be the best practicable answer, and he was glad that the "Knitmesh" installation was recommended. While it was true that such filters had proved extraordinarily effective, he emphasized that their effectiveness depended entirely on correct installation, and any design must allow for correct air velocity through the mesh, correct drainage and facilities for washing pads periodically. The configuration and area of the knitted mesh array was thus closely prescribed.

Figures were quoted for salt content. The Ministry of Defence admitted that they did not know all the answers to salt attack at present, the main reason for this being that hitherto the methods of measurement which had been available had been somewhat unwieldy and unreliable. Progress was being made in this respect and it was confidently expected that the understanding of the problems would be vastly improved in the near future.

While there was nothing which caused undue worry about the current gas turbine projects, and in particular Olympus, he asked that current statements of engine tolerance related to salt content be viewed with some reserve as they were probably based on old measurement techniques.

The author had referred to the integration of ducting into the ship design. In the case of naval vessels this was not an easy task because the requirement to minimize pressure losses through the ducting had to be balanced against the losses of space and hull strength incurred in running large ducts through the ship. Although the Ministry of Defence would like to adopt the figure quoted in the paper of 30 ft/s air velocity in the intake duct, where the power lost per unit pressure drop was greatest, in practice the ducts in the Royal Navy had velocities from two and a half to three times as great as this. The loss in performance had to be accepted, but with careful design the loss of power in the combined inlet and exit ducting was limited to five or six per cent of full power under S.A. conditions. Any measures to increase specific power would produce dividends in easing this problem.

Finally, concerning the reference, under "Future Developments", to a turbine operating with maximum cycle temperature of 1500°K, did this development imply a change of material or was it an extension of currently practised techniques? Engines operating in this range were obviously attractive in the naval context and he would appreciate the author's view of the anticipated time scale for such a development.

Correspondence

COMMANDER H. DEKKER, R.Neth.N., in a written contribution, referred to two great advantages of this advanced type of prime mover—rotary movement and an incorporated heat source. He also commented that quite a few Continental navies were either on the point of introducing gas turbines for main propulsion, both for boost and cruising, or had already done so.

There was no indication in the paper as to whether each of the two fuel pumps mentioned was dimensioned to meet all fuel requirements or whether both were essential over the full power range.

The author had explained that the fuel-control box set the compressor speeds as required by the throttle actuator, the power turbine finding its own speed when the required torque equalled the available torque. Other gas-turbine installations were at sea, in which ship's speed was controlled by changes of propeller pitch at constant rev/min of the shaft and, therefore, constant speed of the power turbine, a method also used in some turbo-prop aircraft. Would the efficiency of the existing design of single-stage impulse/reaction type of Olympus power turbine also be higher within certain power limits, at constant rev/min, apart from propeller efficiency and other factors?

During the discussion on smoke, the author stated that, at power outputs below 50 per cent of full load, some smoke was produced. Did this smoke become more intense as power was further reduced? Also, what was the situation when idling? Although the paper dealt mainly with the Olympus, a comparison with the marine Proteus, in this connexion, would be interesting.

MR. M. HARPER (Member) wrote that he was sure that it was wiser to "marinize" a proved unit such as the Olympus, with all the advantages this gave, than to embark on a new design specifically for marine application. The author had fully listed the advantages and pointed out the snags.

The conception of a relatively short-life gas generator which could be replaced by a reconditioned unit and a long-life power turbine appeared to fit the conditions imposed by present technology.

Control of the gas turbine required rather complicated units. Could the author comment on the reliability of the system?

It was interesting to note the power "map" and the point made that wide variations in turbine rev/min were possible at any power setting without serious loss in power or efficiency. He agreed that this could be useful when a fixed-pitch propeller was fitted, but late comments upon the difficulty of providing astern power led to the conclusion that a controllable-pitch propeller was preferable.

With a controllable-pitch propeller, bridge control using a combination system was considered to be advantageous. Could the author comment on experience with a gas turbine propulsion unit and controllable-pitch propeller using bridge control?

The author had highlighted the problem caused by the size of the exhaust and inlet ducting and mentioned the interesting possibility of mounting the gas generator vertically in the line of inlet ducting. Had any means been developed to lower the ambient temperature, thus enabling a reduction in ducting size?

MR. G. R. STRACHAN, M.A. (Member) wrote that he was interested to read the author's views on the COGAG and other machinery arrangements that the all gas turbine ship would be the future trend in vessels requiring up to 100 000 shp. Mr. Strachan supported this view, but considered that the trend for merchant vessel propulsion would be to adopt gas turbines of the heavy duty industrial type where high utilization or long endurance was required.

These engines, already proven in land usage with some 20 000 000 hours of operational experience to their credit, might be heavier and slightly larger than the aero engine derivative, but their ability to burn both Diesel and residual fuels successfully, together with their excellent maintenance and reliability, made them strong contenders when the overall economics of certain installations were appraised.

Mr. Strachan was, perhaps, inviting some scepticism when he contended that the reason why the marine experience of the industrial type of gas turbine was limited was that the world demand for land based industrial gas turbines had increased at such a rate that the major producers of these units had had to "let slide" the marine side in order to satisfy the appetite of the land markets. However, these were the facts and, had it not been for this phenomenal growth and increased demand (sales of industrial gas turbine horsepower had increased 530 per cent over the past six years), it was considered that by now the industrial type would have made inroads into the marine market —hitherto the domain of the aero engine derivative.

Although, as designed today, the industrial unit occupied more space than its competitor, it still showed significant savings in space over a slow-speed Diesel or steam turbine installation.

It must be admitted that the industrial gas turbine designers had not seriously had to contend with space restrictions and emphasis had been on the simplicity of an in-line arrangement. However, with a small degree of engineering, the overall length of the industrial unit could be shortened to a significant degree by such artifices as vertically mounted starting motors.

Although the industrial turbine operated at a higher firing temperature (1700°F, 926°C) than the marine version of the aero engine, it had a lower pressure ratio and consequently fuel consumptions were slightly higher and thermal efficiencies were slightly lower at 0·56 lb/bhp-h and 24·3 per cent respectively for continuous operation, but the overall effect of these differences was marginal (particularly when the respective fuel costs between aircraft derivative and industrial machines could be in the ratio of as much as 2 : 1).

However, with the ability to incorporate a regenerator in the cycle, efficiencies of over 32 per cent were attainable and, for a continuous base load operation of over 5000 hours per annum, the additional capital cost involved became economically justified.

In 1956 the *John Sergeant*, incorporating a regenerative cycle industrial gas turbine, returned a fuel consumption of 0·52 lb/shp-h when burning residual fuel. With the advances made today in gas turbine technology, a comparable figure of 0·45 lb/shp-h could be achieved.

Whether or not an operator wished to run on residual fuel must depend on many factors, but principally these would be the differential cost between distillate and residual fuels, the trading route, and also the acceptance of the additional complication of a fuel treatment plant and increased maintenance costs. Again, however, the facts were that residual fuel operation, although not popular with operators, was entirely feasible and to prove this there were over 100 installations at present in use throughout the world.

There were several possible marine applications for industrial gas turbines, but an ideal one would be for a cross-channel ferry, or similar short haul vessel. Fuel treatment plant could be kept ashore and washed and treated fuel only taken on aboard. The short crossing of a few hours would reduce performance fall-out to a minimum by virtue of deposits on the compressor being shed automatically when starting up after a shut-down of an hour or two.

Thus the industrial unit had, in his view, the advantages of superior maintenance, higher thermal efficiency by the incorporation of regenerators and the ability to burn many grades of residual fuels, as against some disadvantages when compared to the aero engine derivative.

It was perhaps too much to hope that the author would agree with these remarks, but Mr. Strachan would like to have his views on whether he considered that there was a place in marine installations for the industrial unit, albeit in different applications from the aero engine type.

Author's Reply

In his reply the author first of all thanked all who had taken part in the discussion on the paper and also those who had supplied written contributions. Their participation had been particularly valuable as they had largely represented the point of view of ship designers, who were faced with the problem of installing the engines, or operators who were faced with the possibility of operating this new type of main propulsion engine.

A number of the contributors had raised similar questions and he had adopted the policy of trying to reply as fully as possible to each question in the section dealing with the first contributor who raised it.

Commander Good had raised a large number of questions in his valuable contribution and these were dealt with in the order in which they were raised.

1) *Smoke.* The problem of eliminating smoke from the exhaust of the gas turbine engine when burning Diesel fuel was one of some difficulty and, despite the fact that considerable progress had been made up to the present time, it was realized that there was still room for improvement. The formation of smoke was dependent on the precise combustion process occurring in the primary zone of the combustion chamber and was influenced by minor changes to the nozzle spray pattern and to the introduction of combustion air into the primary zone. The best that had been achieved to date was that virtually smoke-free combustion was achieved from full power down to about half power. From this point downwards the amount of smoke emitted increased and seemed to reach a maximum at about 6000 hp. Although precise measurements had not been taken, the smoke at this point was by no means dense and corresponded approximately to "Ringelman 1". Between 6000 hp and idling, the smoke emission tended to decrease again, probably due to the reduction in total exhaust gas volume.

2) *Power Turbine Design.* The reason for the choice of a single-stage power turbine for the TM.1 was that it was desired to keep the turbine as simple as possible and, as there was no external restriction to turbine rotational speed as there would be in the case of a turbine required for electrical generation, it was possible to provide adequate mean blade speeds in a single stage to obtain high blading efficiency. It was, in fact, true that the estimated blading efficiency of the single-stage marine turbine was some $1\frac{1}{2}$ per cent higher than on the company's two-stage turbine for electrical generation. The only penalty involved was an increase in turbine exit velocity which required careful design of the exhaust duct in the vicinity of the turbine to avoid high leaving losses. Although the leaving losses were some 25 per cent to 30 per cent higher than those in the industrial turbine, the outlet Mach number from the blading was still below 0·5.

It was true however that any large increase in the temperature drop through the power turbine, which might be occasioned by further development of the gas generator to a considerably higher power, would probably necessitate the design of a new two-stage turbine, but the present turbine was quite capable of dealing with any increase in gas generator performance visualized for the immediate future.

3) *Cruising Engine Powers.* The author agreed that the problem of providing the best cruising gas turbine for a ship was one of some complexity and it would be necessary to guard against overstressing the cruising engine in order to obtain the best range at intermediate power. This was not really a decision which should be left in the hands of a ship operator and cruising engines would be normally limited to the maximum power allowed for cruising by deliberately limiting the maximum output from the engine fuel pump.

With regard to the figures in the paper given for the range with a cruising Diesel engine, the author thought that the discrepancies between Commander Good's figures and his own were due to the difference in size of the Diesel engines chosen. The Diesel engine shown in the paper was a very large one and it would probably not be possible to accommodate such a large Diesel engine in the type of vessel being considered. At low cruising speeds this Diesel engine was working well below its best efficiency point with a corresponding reduction in range.

On the subject of intake duct velocity, the author agreed that a velocity of 30 ft/s was seldom obtainable. A review of real installations showed that this figure was nearer 50 ft/s. Furthermore, in the region of the silencing splitters, the velocity increased further and could in fact reach 90 ft/s.

In any case the author agreed completely with Commander Good that ducts should be kept as straight as possible.

The author thanked Commander Good for drawing his attention to an error in Fig. 7 where shaft horsepower was quoted when brake horsepower was meant. This had now been corrected in the paper.

Finally the author agreed that, for correct installation of "Knitmesh" pads, these should not be truly horizontal.

Captain Satow's remarks on the importance of through costing were fully appreciated as this was the figure that really mattered to the operator.

On the subject of the use of this type of engine in commercial vessels, such as a big tanker, it seemed difficult, at the moment, to reconcile the somewhat low thermal efficiencies of the gas turbine engine and their requirements for high-grade fuel with the fuel cost requirements in the operation of such a vessel. However, the thermal efficiencies of a gas turbine plant would undoubtedly increase rapidly in the next few years and requirements for such an engine in a specialized tanker might well arise. This matter was being kept under active review.

Mr. Milton's comments on the low figure for the horsepower per pound of air in the gas turbine engine were accepted, although the paper drew attention to the possibility of big improvements in this figure in the not too distant future. The basic reason for the present state of affairs was that the gas turbine required very much larger quantities of excess air than, for instance, was required by a modern boiler furnace. For the same type of ship in which the Olympus gas turbine was being used, a steam turbine would probably provide some 470 hp/lb air/s and 420 hp/lb steam/s.

The author did not believe that, at the present time, there was much hope of making the simple gas turbine use residual fuel. Undoubtedly this could be done, but only at the expense of reducing the maximum cycle temperature, with a resulting decrease in engine performance. The final outcome tended towards making the engine less competitive.

With regard to the life of the gas turbine and the cost of its repair after service, there were indications that service experience would tend to increase the life between overhauls considerably and, if the engine was used at or below its cruising power, figures of 10 000 hours or more were not beyond possible expectations. It was difficult to assess the cost of overhaul with any great accuracy at the present time, but a figure of 15 per cent of the new cost of the engine was of the right order.

The basic reason for splitting the gas generator into two independent units was entirely a matter of providing stable operation of a high compression ratio gas generator at part load and under acceleration conditions. The mechanical problems were now well understood and gave rise to no operational problems. In the author's opinion, this method of achieving stability of operation was preferable to the alternative method of providing variable blade geometry in a one-piece high-compression compressor.

With regard to the question of compressor washing, while this would probably be required daily in harbour, it would not be required so frequently at sea, unless salt water entered the engine intake. Methods of engine cleaning were receiving very active consideration and it should be possible in the future to effect this washing under normal operating conditions.

Commander Thomas had drawn the author's attention, very correctly, to the fact that the fuel consumption of an engine alone was not the only, if indeed, the main consideration in choosing the best type of engine for a given operational requirement. Undoubtedly the small bulk and weight of the gas turbine engine was one of its main attractions in competition with other types of engine and, in many cases, more than compensated for the high fuel consumption compared, for instance, with the Diesel engine. A comparison on the basis of engine plus fuel weight was a better comparison, but this was still a simplification of the situation and, in fact, a final decision could only be taken after a very detailed study in each case. The author fully agreed that, in the case of naval vessels presently being fitted with these engines, simple arrangements were the best arrangements.

Commander Smith had referred to the effect on time between overhauls of the maximum cycle temperature at which the engine was operated. This was undoubtedly important especially at the higher power and, if periods of 6000 hours were to be obtained between overhauls, it was essential to keep the running at high powers down to an absolute minimum. There could easily be a factor of 4 in expected life between operating at cruising power and at normal maximum power, and this factor could increase to something in the region of 20 between cruising power and the maximum power at which the engine could safely be used for continuous operation. It was important to realize that the gas turbine was an engine which could be used continuously at very high powers indeed, provided a short time between overhauls was accepted.

Whenever powers were being talked about it was important to differentiate between the standard brake horsepower of the engine at I.C.A.N. conditions on the test bed and the installed shaft horsepower, allowing for installation losses, gearing losses and ambient temperature conditions.

The author thanked Commander Smith for his comments on salt attack. The figures presented in the paper were admittedly subject to modification as a result of the intensive work going on at the moment on salt separation, the measurement of salt quantities in the air and on the further development of the engine components to resist salt attack.

With regard to the comment on the use of very much higher turbine inlet temperatures in the future, these would normally follow in the wake of aero engine development and would probably involve the extensive use of blade-cooling techniques and perhaps some change in blade material. For the marine engine it was unfortunate that many of the newer materials capable of operating at higher temperatures were also more subject to corrosion attack, but considerable increases could be made in the present top temperature use, merely by using blade-cooling techniques with present-day materials. This alone however would probably not achieve successful operation at 1500°K [1227°C (2241°F)].

Mr. Forbes had rightly drawn attention to the important effect on oil coolers of the differences between the bearing and lubrication arrangements of the gas generator, which were in accordance with normal aircraft engine practice, and those of conventional plain bearing machinery. Some comments on the gas generator bearing operation might be of interest.

The operation of aero gas turbines demanded quick starting, under all conditions, down to temperatures well below freezing point and, therefore, anti-friction bearings were essential. Furthermore, the bearings must be capable of operation at the highest possible temperature, if undue losses due to heat insulation and cooling were to be avoided. The development of special materials for bearing races, rollers and balls and of special synthetic lubricating oils had resulted from this requirement. The synthetic oils possessed the two important characteristics of low viscosity index and stability at high temperatures and, while remaining free flowing down to −40°C (−40°F) or lower, could be used at temperatures above 150°C (302°F) without serious deterioration. Typical maximum bearing operating temperatures for the thrust bearings were 180°-190°C (356°-374°F) and maximum scavenge oil temperatures were about 150°C (302°F).

The low friction coefficient of the bearings themselves and the high temperature of the oil was, as Mr. Forbes had said, the reason for the small size of cooler required, but this was only a by-product of the intensive research and development effort which had gone into solving the difficult operational and design problems posed by the aero engine. It was interesting to speculate what might be the overall effect of applying some of these advanced techniques to the other items in the propulsion machinery of a warship, such as the power turbine and main reduction gear. The present policy was to use conventional plain bearing designs in the power turbine and integrate the power turbine lubricating system with that of the main reduction gearing, and on balance this seemed to be the safest and best policy.

In reply to Mr. Harper, the author said that the basic control system of the gas turbine was actually quite simple and gave a high degree of reliability. In order to prevent serious damage to the engine due to any mishandling or malfunctioning, there was admittedly a considerable number of safety devices, some of which had to be designed to work very rapidly indeed. A number of the devices was required to guard against contingencies which were very unlikely to arise, but the results of which would be disastrous. It was always difficult in these circumstances to design the safety device to have a better degree of reliability than the component it was to safeguard. The author's company had now had enough experience at sea with its smaller engines, in the fast patrol boat type of vessel, to believe that once the initial difficulties had been ironed out, the whole system worked with an adequate degree of reliability and serviceability.

On the subject of bridge control using controls in conjunction with controllable-pitch propellers, a very good example of such a system was given by the new Swedish class of fast patrol boats fitted with three Proteus engines. The degree of manœuvrability of this vessel, from the bridge, was quite remarkable. Even when a controllable-pitch propeller was fitted to a vessel, however, the advantages of the free power turbine in providing constant power over a range of propeller speeds was useful in that it allowed one to operate the propeller at its best pitch. There was evidence that the change in propeller efficiency, away from the best pitch point, was more rapid than the change in efficiency of the power turbine from its best speed point.

The idea of increasing the power of the engine by reducing the air intake temperature was handicapped by the large air consumption of the gas turbine. Evaporative cooling was sometimes used on land, but its success depended upon a low air humidity and a cheap supply of fresh water. For these reasons it was unlikely that this method could be used at sea.

The large amount of air breathed militated against any other methods of reducing air inlet temperature.

Concerning Commander Dekker's contribution, each of the two fuel pumps on the Olympus gas generator was capable of supplying all the fuel required for the engine at full power. The additional control devices, however, which would be required to make this an operational feature of the engine had proved, in the past, to be less reliable than the fuel pumps themselves and, in fact, failure of the fuel pumps in service almost never occurred. The engine was therefore operated without the possibility of using the fuel pumps independently. The pumps shared the load, thereby ensuring long life.

The characteristics of the single-stage turbine were shown in Fig. 8 and the line of best efficiency against power followed approximately a cube law. It would be seen however that the curves were quite flat and the loss occurring by running at constant speed over the top half of the power range was not very great.

The author was very interested in Mr. Strachan's contribution. On the vexed question of "industrial" type gas turbines versus "aero engine" gas turbines, it was the author's opinion that at any given time the gas generator based on aero engine background would always be a better "state of the art" unit than its industrial counterpart. However, the author believed that a much more important consideration was whether one used a high-temperature simple-cycle engine with exhaust recovery or a recuperative-cycle engine. In either case, there were such great advantages to be obtained in a gas turbine, by operating at a high temperature, that the author was quite unrepentant in believing that better results would come from work directed towards increasing maximum cycle temperature, rather than in complicating the cycle in order to be able to operate efficiently at the lower temperatures demanded by the use of residual fuel.

One of the great advantages of the simple-cycle engine with exhaust reheat recovery was the very much greater possibility of reducing the air consumption of the engine for a given horsepower output, which affected not only the bulk of the engine, but the whole of its installation in the ship. This was especially true of ships which required high power installations. This effect tended also to increase as the maximum cycle increased, but even at cycle temperatures which were operational today, Table III showed considerable advantages for the simple-cycle engine with exhaust heat recovery.

TABLE III—COMPARISON BETWEEN REGENERATIVE-CYCLE GAS TURBINE AND SIMPLE-CYCLE GAS TURBINE WITH AND WITHOUT EXHAUST HEAT RECOVERY

Maximum cycle temperature	1150°K[877°C(1611°F)]
Heat exchange thermal ratio	0·8
Heat exchange pressure loss	5 per cent*
Approximately optimum cycle compression ratio	

	Compression ratio	Bhp/lb air/s	Thermal efficiency per cent
Simple-cycle turbine	11	108	27
Simple-cycle turbine with exhaust recovery	11	140	37
Regenerative-cycle turbine	6	96	33
Regenerative-cycle turbine with reheat to maximum temperature before power turbine	6	107	31

*Heat exchange pressure loss $= \left(\frac{\text{Air-side loss}}{\text{Compression delivery pressure}} + \frac{\text{Gas-side loss}}{\text{Turbine exit pressure}}\right)$

It was true that, at the moment, the simple-cycle gas turbine did not show to advantage in a merchant vessel, where there was ample space available for a Diesel engine of the necessary power. A better case could probably be made at the moment for an "industrial" type of gas turbine using a regenerative cycle, but this still did not seem to compete with the Diesel engine. The future in this role was much less clear, but the author still believed that the simple-cycle engine with exhaust heat recovery offered a better possibility than the regenerative gas turbine.

Annual Dinner

The Sixty-fourth Annual Dinner of the Institute was held on Friday, 10th March 1967, at Grosvenor House, Park Lane, London, W.1 and was attended by some 1495 members and guests.

The President, Sir Stewart MacTier, C.B.E., B.A. was in the Chair. He was supported by the Chairman of Council, Mr. R. R. Strachan, C.B.E., Mr. J. McAfee, Vice-Chairman of Council, and the Chairman of the Social Events Committee, Mr. Stewart Hogg, O.B.E.

The official guests included: His Excellency Baron Jean van den Bosch, The Belgian Ambassador; His Excellency Sir Lalita Rajapakse, LL.D., Q.C., The High Commissioner of Ceylon; P. N. Haksar, Esq., The Acting High Commissioner for India; Captain 1st Rank B. Polikarpov, U.S.S.R.N., Naval Attaché, representing His Excellency the Soviet Ambassador; The Right Honourable the Viscount Simon, C.M.G., President, The Royal Institution of Naval Architects (Past President); Sir Gilmour Jenkins, K.C.B., K.B.E., M.C., Past President; J. P. W. Mallalieu, Esq., M.P., Minister of State, Board of Trade; Sir Richard Clarke, K.C.B., O.B.E., Permanent Secretary, Ministry of Technology; Vice-Admiral Sir Frank Mason, K.C.B., President-elect; Sir William Swallow, Chairman, Shipbuilding Industry Board; F. I. Geddes, Esq., M.B.E., Chairman, The British Shipping Federation; F. B. Bolton, Esq., M.C., Immediate Past President, The Chamber of Shipping of the United Kingdom; Captain L. W. L. Argles, C.B.E., D.S.C., R.N., Captain Superintendent, The Thames Nautical Training College; D. Beavis, Esq., President, The Institution of Gas Engineers; R. W. Bullmore, Esq., M.B.E., Assistant Secretary, Board of Trade; J. Calderwood, Esq., M.Sc., Honorary Member; J. Carr, Esq., Denny Gold Medallist 1966; R. Cook, Esq., M.Sc., Honorary Treasurer; The Reverend Maurice Dean, B.A., The Rector, St. Olave's, Hart Street, London, E.C.3; Edward L. Denny, Esq., B.Sc., Past President; G. W. Hill, Esq., M.B.E., President, The Society of Consulting Marine Engineers and Ship Surveyors; Stewart Hogg, Esq., O.B.E., Chairman, Social Events Committee; G. G. Howard, Esq., Managing Secretary, The Salvage Associ-

The President of the Institute, Sir Stewart MacTier, C.B.E., B.A. (centre), with the Chairman of Council, Mr. R. R. Strachan, C.B.E. (on right) receiving guests at the reception before the Annual Dinner held on Friday, 10th March 1967, at Grosvenor House, Park Lane, London, W.1 ation; A. G. Howe, Esq., M.B.E., President, The Diesel Engineers and Users Association; Dr. R. Hurst, G.M., Director of Research, The British Ship Research Association; M. Langballe, Esq., Institute Silver Medallist 1966; J. Leckie, Esq., C.B., Deputy Secretary, Ministry of Technology; A. Logan, Esq., O.B.E., Past President; A. J. Marr, Esq., President, The North East Coast Institution of Engineers and Shipbuilders; Dr. D. C. Martin, C.B.E., Executive Secretary, The Royal Society; Dr. D. D. Matthews, M.A., M.Sc., President, The Institution of Structural Engineers; J. Neumann, Esq., B.Sc., Denny Gold Medallist 1966; H. N. Pemberton, Esq., Chairman, Council of Engineering Institutions; J. A. R. Pimlott, Esq., C.B., Under Secretary, Department of Education and Science; C. C. Pounder, Esq., Past President; P. C. M. Sedgwick, Esq., The Director, Hong Kong Government Office; A. Storey, Esq., Chairman, The National Association of Marine Enginebuilders; R. R. Strachan, Esq., C.B.E., Chairman of Council; D. S. Tennant, Esq., C.B.E., General Secretary, The Merchant Navy and Air Line Officers Association; Ronald Ward, Esq., F.R.I.B.A.; Victor Wilkins, Esq., F.R.I.B.A.; A. W. Wood, Esq.; C.B.E., Assistant Secretary, Board of Trade.

The Loyal Toasts having been duly honoured:

His Excellency BARON J. VAN DEN BOSCH, The Belgian Ambassador, proposed the toast of "The Royal and Merchant Navies of the British Commonwealth".

He said: "The privilege of being called upon to propose the toast of 'The Royal and Merchant Navies of the British Commonwealth' is indeed a great one. I am afraid, however, that this is an honour fraught with danger, and not only for me but obviously for the numerous distinguished people gathered here. It is difficult for an alien or is it now a foreigner (anyway both terms are better than the Roman term of 'Barbarians') however hard he may try, fully to understand some of the institutions of this fair island, such as cricket, the Lloyds and the Royal Navy, as everyone knows, the British Navy is a very different affair from all the other Navies in the world!

I have had, I must admit, some personal connexions with the Royal Navy which were extremely pleasant to start with and very revealing to follow. The first of them relates to the days of gunboat policy, when you had in China a rather odd looking flotilla cruising on the Yangtze river. There were some queer names, H.M.S. *Gnat*, H.M.S. *Bee*, H.M.S. *Ladybird*, and so on, with on board of each two officers and about fifty naval ratings, cruising up and down the Yangtze. This was quite fun, and I had the privilege to be asked on board from time to time. I remember one occasion in the early Chinese spring and it was rather crisp outside, so that one was quite pleased to get down to the ward room. On board there was a newly commissioned midshipman who had arrived the day before and was at sea for the first time. The skipper and I had had a couple of gins before lunch, when his new Number Two came up to me and very kindly said, 'would you like another drink?' I thought it very nice, when I saw the face of the skipper darken. He gave a nasty look to the midshipman, who rushed out and was never seen again. The captain said, 'I do apologize. Never aboard my ship is a guest asked if he wants another drink'.

The second occasion I would like to mention was during the War. The Allied landing was about to take place. The Admiralty was recruiting among the Allies in Britain civilian liaison officers to be put on landing craft, who knew the coast of the Continent and the people on the shores rather well, in order to be able to talk with them and make contact with the local authorities, and so on. We were asked to produce ten suitable Belgians who could be commissioned Lieutenant R.N.V.R. We had few suitable prospective naval officers, but we had a number of fishermen from Ostend who came to this country and spent the War providing you with excellent fish. They had large blue pants, very often clogs and ear-rings, and little caps, and spoke only Flemish. The recruiting officer took half a dozen of them and they completely disappeared. They reappeared three weeks later speaking King's English, holding their brown gloves in their left hand, with stiff collars and bow ties, and able to pass the port in the right direction. What had been done with our Ostend fishermen in three weeks by the Navy was out of this world!

Those are two experiences which make me think of the Navy with wonder and admiration.

What I do appreciate in the task that has fallen upon me tonight is the tradition of this Institute to merge in the same toast the Royal and the Merchant Navies. Indeed, as you go through History, one cannot imagine in any country two public services so closely interwoven as the two British Navies. Your seafaring tradition starts more or less with the privateers—and maybe on some of their accomplishments, the least said the better; however your minds may be at rest, if you had your privateers, we had our buccaneers and they were no better, possibly worse—but both certainly struck a clever balance between personal profits and adventurous action, combining therefore in their own personal way what later became the separate activities of each Navy.

In that respect, I was recently reminded of a former compatriot of mine, named Le Mel—who came from Liège, which is really some distance from the sea—and who, in 1695, sailed up the Thames Estuary on a 30 ton ship, slipped breezily by the front of a whole squadron of the Royal Navy at anchor, got hold of five merchant ships and escaped safely although pursued by forty craft. One should not worry . . . we have now stopped indulging in such errands—at the most some of our fishermen trespass the limits and go in for a little fishing in British territorial waters, which from time to time ends up in court, much to our fishermen's sorrow!

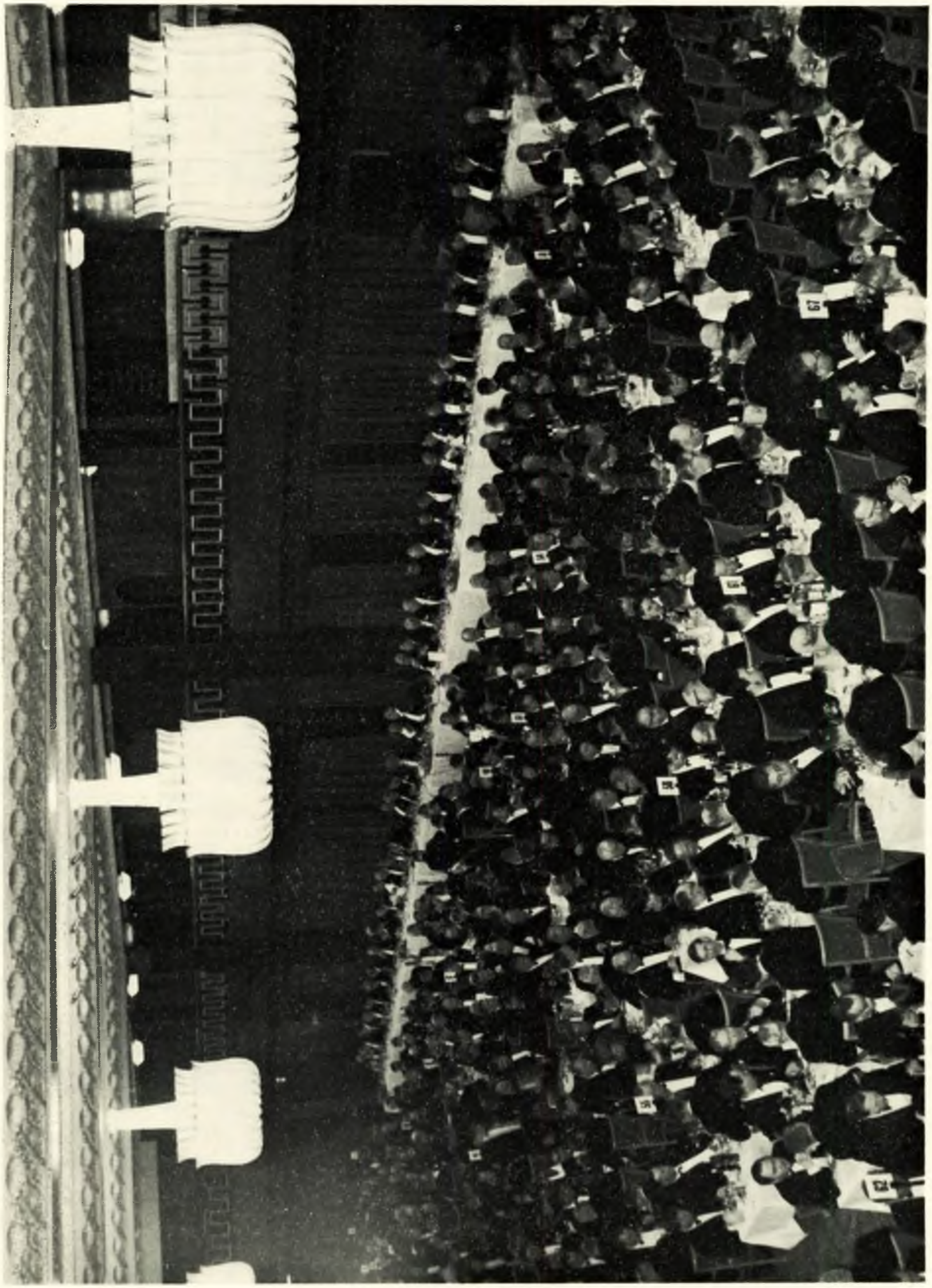
What I really intended to stress was how much the development of the British Empire owed to the co-operation of both Navies.

It is, of course, possible that the Royal Navy opened in some cases old Dutch, French or Spanish colonies to trade, but I believe that in many more cases—having the China clipper in mind—it is the merchants who went out first, ploughing the Seven Seas with British goods and opening new shores to trade and commerce. They seemed happy to do so without outside help as long as they did not land themselves into trouble, but attached as they were to economic freedom, they would enlist the help of the Royal Navy each time such freedom had to be preserved; the co-operation between the two Navies grew indeed so intimate that since Henry V, who separated one from the other, I believe that navigators of the Royal ships came from merchant vessels and frequently returned to them. When the Empire reached in the Nineteenth Century the zenith of its glory, a *Pax Britannica* ensued during which the Empire carried on, thanks mainly to the Navy, an expansion which rose from 1 500 000 square miles in 1800 to 11 000 000 square miles at the beginning of this century. Such progress is, of course, unthinkable without the spirit of enterprise and adventure of one service and the determination and resourcefulness of the other.

The two world wars which have so far marked the Twentieth Century, far from separating one navy from the other, brought them closer together than they had ever been throughout history. Indeed, the aim of the enemy was not essentially to destroy men-of-war a difficult task indeed—which would have involved great risks, and their action limited itself to sink relentlessly as many merchant vessels as possible whether they carried Scotch whisky or whether they brought back men, goods, military equipment or foodstuffs to these besieged islands.

Indeed the convoys suffered heavily, but never faltered, thanks to the skill and courage of the officers and sailors and to the constant protection afforded by the Royal Navy and the Fleet Air Arm.

Such protection was so essential to the successful conclusion of the War that all Allied Forces in Britain, however small, joined in, and Belgium owes to its co-operation with the Navies of England in the war the birth of its own present



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naval force which since 1946 carries on the tradition of the Belgian Section of the Royal Navy.

Once upon a time, we had a Navy of our own, a so-called 'Marine Royale' from 1830 to 1862 when it was disbanded and a 'Corps des torpilleurs et marins' from 1918 to 1926 when once again it was disbanded.

To-day forty-seven minesweepers, specializing in mine counter-measures warfare, are fulfilling their task at the centre of the Atlantic Alliance.

This reference might seem irrelevant on this occasion and in front of this distinguished gathering, but if I mentioned the Belgian Navy my purpose was only to stress the close relationship which existed between the Royal Navy and our own during the War. This relationship is still thriving to-day in an atmosphere of friendship and trust which cannot be belied.

It was already said three centuries ago that 'the first Article of an Englishman's creed must be that he believeth in the sea'.

We, friends and allies of Britain, have many good reasons to thank God that deep-rooted in your minds and in your hearts are such a creed and such a belief.

Therefore, it is with a feeling of gratitude and admiration that I propose the toast this evening to the Royal and Merchant Navies of the British Commonwealth coupled with the name of Mr. Bolton, Immediate Past President of the Chamber of Shipping of the United Kingdom."

Mr. F. B. Bolton, M.C., Immediate Past President for the Chamber of Shipping of the United Kingdom, in reply, said:

"I heard somewhere the other day that a suggestion had been made that the title of the seaman's grade in the Royal Navy should be altered to include the word 'mechanic'. If this is true, it demonstrates the power of the spirit of engineering, the implication being that nobody ashore is today prepared to give a job to anyone who has not apparently been trained in the mechanical sciences. I was going to say that I do not see any signs yet of this spreading to the Merchant Navy to the extent, for instance, that a mate would like to have his title changed to second engineer (deck); but I have been reading the recently published Pearson Report and I am not so sure that something of this sort may not lie behind some of the thought contained therein.

It is with this real awareness of the significance of engineers at sea, and the bond—if it is no stronger than this—forged by the demand for engineering skills, which is uniting the highly sophisticated Royal Naval ships and the nearly as sophisticated modern cargo liners, that I am so glad to be given the opportunity of responding to the toast of 'The Royal and Merchant Navies of the British Commonwealth', so kindly proposed by the Belgian Ambassador—bracketing with them, as he did, the privateers as well!

I have fewer qualifications now to speak for the Merchant Navy than I had a few weeks ago, and none at all to speak for the Royal Navy. My service years were spent in the Army and I am now out of office as President of the Chamber of Shipping—a fact which will no doubt be welcome to those of you here who have had to listen to me on more than one occasion over the last year. Don't worry. It is the last time!

I was speaking just now about the ubiquity of the marine engineer in the Royal Navy and the relative eclipse in the Royal Navy of the equivalent of the deck department, and I wonder what are the implications in the Merchant Navy in this connexion of the Pearson Report. A first reading of the Pearson Report makes it clear that the Committee were obviously impressed with the changes either in progress or impending in the Merchant Navy today—changes in the technical sphere and in the trading pattern which clearly will involve entirely new types of ship and mean new skills for crews and changes in the methods of remuneration. Perhaps the most striking impression that can be obtained from a first reading of the report is the plea for flexibility, and is this not the right note for marine engineers generally as well? Rigid thought is always harmful, and perhaps our critics, both at home and abroad, are right when they accuse us as a nation of being too rigid in our national attitudes. Rigidity of mind in the middle of such technological changes as we are now facing, particularly at sea, is more than doubly harmful. Flexibility does not mean inability to make up one's mind. I even wonder whether it is true that there is a point after which changes in design and detail will not be permitted in the building of capital ships of the Royal Navy. I have always understood this to be the case and that this was the reason why it took fifteen years to build a battleship or a nuclear submarine! (*Applause*). Certainly in the Merchant Navy I am sure we are allowed far too much liberty, as owners, to change our minds and to introduce modifications into our ships, right up to the last moment almost of delivery! (*Applause*). This is something which I am sure the Japanese have to teach both shipowners and shipbuilders. In the context of building merchant ships at least flexibility does mean the abandoning of the concept of one-off and accepting sensible ideas of standardization. In training it does not mean delaying the adoption of new standards until the future pattern emerges. After all, the man we are training today will not be a chief engineer for ten years or so, so time is not on our side. But it does mean establishing syllabuses and keeping them up-to-date. In equipment it means never being satisfied with what we have as the ultimate. The best can be improved upon and the perfect can be improved and probably should be, for if it is perfect it has been there for a long time and it is time it was replaced. If we ship operators under the red and white ensign are to get the best ships for our respective purposes, we must concentrate as much as, perhaps even more than, we are now, on what is slowing down technical progress and what areas of high cost or technical weakness will respond to investigation. We have got to keep flexible minds and make the best use of professional skills, like those of the members of your profession, and to continue and broaden the processes of exchange and the results of thought between the two Navies and amongst each other.

The Royal Navy and the Merchant Navy have different requirements. I do not know which of us it was that the Prime Minister had in mind when he told the House of Commons that in a loose classification of the Board of Trade 'locomotives, ships and aircraft' should have read 'wire mattresses, lugs, nails and manhole covers'. (*Laughter*) But the Royal Navy wants the most efficient in terms of what the ship can do and the Merchant Navy wants the most efficient in terms of cost, not first cost only but first cost, running cost, repair cost, fuel cost, manning cost, and it does not want materials that cost the earth and burn out under maximum load. Both Navies want the same services from the marine engineer and, happily, they get them from you.

I do not know about the Royal Navy but the trouble with the Merchant Navy is the competition of shore employment. The problem is how to make seagoing employment for the engineer sufficiently attractive to retain his services at sea over a longer period than we are experiencing now.

Finally, it is important for the layman, the lay manager, to be able to understand what the professional is telling him. A neat illustration of the ease with which misunderstandings can occur is one which is probably more familiar to the Royal Navy than to the Merchant Navy or shipowner, as we do not have so much to do with civil service procedures. It concerns a civil servant who wished to record that something in a memorandum was nonsense and wrote 'Round objects' in the margin. The next day it was returned to him with the further note, 'Who is Round and why does he object?' (*Laughter*) We must always try to say what we mean and say it in terms that the other man will understand!

It is because I am so fully aware of what the Royal and Merchant Navies of the British Commonwealth owe to marine engineers and how much they depend on them for progress in the future that I am very pleased indeed to have had the honour of replying to the toast. (*Applause*)

Sir William Swallow, Chairman of the Shipbuilding Industry Board, proposed the toast of "The Institute of Marine Engineers".

He said: "May I say right away that I feel honoured to have the opportunity of proposing this toast, particularly because I have not been closely acquainted with the work of the marine engineer. In fact, I feel like the old lady who was asked if she had seen Halley's Comet and replied, 'Yes, but only at a distance'. (*Laughter*) This view of marine engineering applies to many people, especially the general public.

One qualification I can claim for proposing this toast is that all my life I have been fundamentally an engineer, and naturally I have had a great admiration for the work of the marine engineer. Also I now have a vested interest in the work of your Institute by reason of my appointment as Chairman of the Shipbuilding Industry Board, already known for short as the S.I.B.—another addition to the proliferation of initials one has to put up with these days. Incidentally, an American friend pointed out the other day that the letter 'O' is next to 'I' on the typewriter, so that a typist could easily make it, 'Chairman, S.O.B.' (*Laughter*)

In recent months, then, my interest in the shipbuilding industry and everything related to it has been intense. My basic text book has been the report of the Geddes Committee. This I consider an outstanding example of what such a report should be. It is not only extremely informative but constructive in its wide ranging comments. I have visited very many shipyards and talked to lots of people at all levels in the industry. My impressions are preliminary ones but they are superimposed on a lifetime's industrial experience. I am not surprised to find that many of their problems are the same as in other industries. They certainly do not seem to be very prosperous, and maybe they are not alone in that either. Unfortunately, the drop in shipbuilding orders has created some gloom and despondency, and pessimism can be contagious. At times I have felt like the policeman who was crossing Waterloo Bridge just as a man was in the act of jumping over the balustrade. The would-be suicide explained that he was intensely depressed and could not see any future at all, so the policeman, being something of a philosopher, persuaded him to walk to the end of the bridge so that he could reason with him and get him to take a more optimistic attitude to life. About half an hour later they walked back to the centre of the bridge and both jumped off. (*Laughter*) I feel that I have been a little more optimistic than that because I am still here! Fortunately, too, the Geddes Committee took a more positive view of the future possibilities of the British shipbuilding industry. In addition to confirming this in my own mind, I have been very much encouraged to find that all the shipyard workers I have talked to were genuinely keen and eager to help the industry regain its share of the world market. With this fund of goodwill and a sustained effort on the part of everyone to endeavour to implement as many as possible of the Geddes Committee recommendations, I feel very confident that the potential which exists throughout the industry can be realized and a better share of the world shipbuilding obtained.

The main objective of the S.I.B. is to assist the industry to become more competitive, and I want to stress 'competitive in cost', for in an industry like yours profit just is not a plus added to cost; rather is it a residue—the difference, if any, between the market price and the cost of production. But one can also be competitive in design, quality, performance, and so on, and it is the job of the S.I.B. to prod, push, assist, and encourage anyone who can make a contribution to furthering the success and prosperity of the industry, and not, as someone said, in an unintentional pun, to get the efficient yard swallowed by the inefficient one.

Following this preamble, my natural tendency tonight is to focus on the marine engineer. After all, a large proportion of the cost of the ship is in his bailiwick and accordingly we are expecting the marine engineer to make a major contribution towards cost reduction and technical development. To a tremendous extent the future success of the industry depends on his ability. I say this because I have always contended that one of the best places to achieve lower costs is on the drawing board, particularly by simplicity of design, but this is one of the most difficult things to achieve—just as it is more difficult to write a short story than a long one.

I sometimes think that the ingenuity of the machine tool engineer has discouraged simplicity of design. Time after time design engineers have boasted to me that the production engineer has been able to produce something that he said he could not possibly make when he first saw it on the drawing board, but at what a cost in time and money! I do not need to tell you that in addition to lower capital cost we can compete in world markets by achieving lower ship operating costs; but these are also very much dependent on the technical skill of the marine engineer, if we are to see the industry grow.

Here again, people who can think up new ideas are scarce, but necessity is the mother of invention, and I am positive that you can prove that not all the brains have gone down the drain. I know that exhortation has long since been overdone, and maybe we ought to hear more about incentives. I know that I must be considered to be one of those characters who rush in where angels fear to tread. But I think I have two advantages. First, I have no conflict of interest; second, from my own experience I know what the engineer can do, if he gets down to it, to put us above our competitors. To paraphrase an old saying, 'If you design and make something better than anyone else, the world will beat a path to your door wherever you are.' In proposing this toast, therefore, I do so with feeling, for if you are doing just that we shall all benefit from your success." (*Applause*)

The President, in reply said:

"We all know that the job of the last speaker on an occasion like this is to be brief, or witty, or both. Whoever it was in the Institute who arranged the order of speaking for this evening must have been well aware that I am totally incapable of making a witty speech and so I can only conclude that he decided that I could be trusted to be brief—I shall do my best not to let him down!

The first thing I have to do on behalf of our members here this evening—and indeed, on behalf of us all—is to thank you, Sir William, very much for proposing the toast of the Institute. We were very interested in your preliminary thoughts on the shipbuilding industry, in which all of us are deeply concerned, and also your general thoughts on the profession of engineering. In reply I have two points to make:

The first concerns the Institute. I know that in this country it is the tradition that professional bodies impose on themselves a strict code of modesty and self-effacement. Of course I respect that attitude, but I am not sure that it is always a good thing. In the case of the Institute of Marine Engineers it is perhaps of some importance that people outside the profession should know a bit about what we are and what we do—if for no better reason than at the present time the British marine industries, with which we are particularly closely connected are having quite a difficult time, and now and then are subject to a certain amount of criticism as being old-fashioned and unscientific in their approach to their business.

Well, as I happen to be in the shipping industry myself, I am entitled to say that as far as we are concerned, such criticism is not wholly unjustified. And so, if the Institute can contribute in the field of stimulating an increasingly scientific approach to our problems in the marine industries—which I think it can—I suggest that it will be doing just what a learned society is intended to do.

I suppose that at the present time the Institute has two principal objectives in view: firstly—as always—the general spread of scientific knowledge in the marine field, and secondly—to encourage the higher education of marine engineers.

It is on this second objective that I should particularly like to comment this evening. I am convinced that in every aspect of marine engineering—from building main propulsion units to electronic monitoring and control gear, there is no substitute for a personal knowledge of working conditions at sea—and don't some of us know it who have tried to adapt land techniques to automated ships! At the same time, I suggest that we in the marine industries in this country must raise our standards of technological competence.

To attain these twin goals it is obviously of the greatest importance that training schemes are developed which will enable seagoing engineer officers to continue to qualify as corporate members of the Institute and so to acquire the status, and of course, the competence of Chartered Engineers. The Council of the Institute has been devoting a great deal of thought to this problem over the past twelve months, and recently we have been discussing some definite proposals with the Shipping Federation and the organizations representing shipbuilding and marine engine building.

This happens to be an immediate and I think an urgent issue in this country today, but of course the Institute has the same general objectives elsewhere in the world and it is interesting I think to reflect that out of our 17 300 members (our membership was 4750 in 1945), 5000 members are resident overseas and that we have twenty-three overseas branches.

Having said that I would like to place on record the fact that much, perhaps most, of the vigorous and world-wide expansion of the Institute's activitites has been due to the enthusiasm and to the enterprise of our Branch organizations in this country and overseas.

So much for the Institute. My second point is to say something about the relationship, as I see it, between the shipping and the ship and engine building industries in this country. In the past I think that ship operators and ship and engine builders have failed to appreciate their interdependence. Ship operators have failed to realize that if they did not feed back operating results to the marine industries ashore, they could hardly expect to get a better job next time, while many ship and engine builders have shown a surprising lack of interest in the operating results of new ships built by them. That attitude of mind in this country is, I hope and believe, a thing of the past in no small degree due to the activitites of the reconstituted British Ship Research Association in collaboration with the Research Committee of the Chamber of Shipping.

So far so good, but the fact is that today the marine industries are confronted with a perfect ferment of change—that is with a speed of change and a speed of development and specialization which has left a lot of us technically and commercially speaking 'gasping'. 'Gasping' that is in the sense that we have found ourselves without the resources of technological manpower or, in some cases, the resources of organization and finance firstly to make an intelligent forecast of future developments and thereafter to take commercial advantage of our knowledge.

As to our manpower problem. I can only mention once again, the enormous and tragic loss—year by year—to the marine industries afloat and ashore of highly qualified and experienced seagoing engineer officers, and to a solution to this problem which I propounded nearly twelve months ago, namely the concept of 'short term commissions' at sea on the built-in understanding of employment thereafter in the marine industries in this term's widest sense—ashore. As far as I know this suggestion, which was not particularly original, has made not the slightest impact on the marine industries, perhaps for very good reasons but I continue to believe that it has real merit in relation to our future prosperity.

The other side of the coin is the question of organization and finance. The modern unit of sea transportation is specialized, very large, very complex and very expensive. Even to assemble the basic data on which the shipowner—or for that matter the shipbuilder who after all has got to sell his wares—can make intelligent decisions on design and cost, involves very heavy overheads by way of staff to cover—operational work study, trade research, really detailed studies of repairs, maintenance and manning costs in relation to the capital cost of automation and many other aspects of the 'scientific assessment' of the economics of ship operation.

All this costs a lot of money and to carry such a burden of overheads, I suggest that both the shipping and the shipbuilding industries will have to develop either in the form of bigger units, or on the basis of much closer collaboration between companies than we have achieved in the past.

But whatever the future, I am sure of one thing, namely, that we are living in a period of great change and of great opportunity for all of us in the shipping and shipbuilding industries, and so for all of us who are members of the Institute of Marine Engineers. Good luck to us all!"

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting held at the Memorial Building on Tuesday, 10th January 1967

An Ordinary Meeting was held by the Institute on Tuesday, 10th January 1967, at 5.30 p.m., when a paper entitled "The Bristol Siddeley Olympus Marine Gas Turbine" by W. H. Lindsey, M.A., C.Eng., F.R.Ae.S., M.I.Mech.E., M.I.Loco.E. (Member) was presented by the author and discussed.

Mr. J. McAfee (Vice-Chairman of Council) was in the Chair and one hundred and ten members and guests were present.

Six speakers took part in the discussion which followed.

The Chairman proposed a vote of thanks to the author which received prolonged acclaim.

The meeting ended at 7.12 p.m.

Branch Meetings

North Midlands

General Meeting

A general meeting of the Branch was held at 7.30 p.m. on Wednesday, 15th March 1967, at the Sheffield Industries Exhibition Centre, Carver Street, Sheffield, when the paper "Freak Ships of the Nineteenth Century" was presented by the author, Mr. J. Guthrie (Member).

Mr. Guthrie, who took as his starting point the introduction of steam, illustrated his presentation with slides of numerous extraordinary types of vessel and traced their development up to the beginning of the present century.

Following the lively question period provoked by the paper, the Chairman of the Branch, Mr. G. Prentice, proposed a vote of thanks to the speaker, pointing out the considerable amount of research which must have gone into producing such an excellent paper. The meeting terminated in applause.

Visit to Unilever

On Wednesday, 19th April 1967, a party of members and their wives were the guests of Unilever Merseyside Ltd., Port Sunlight.

The occasion commenced with a visit to the Lady Lever Art Gallery followed by lunch at the Bridge Inn, where the party was joined by the Chairman of the North West England Branch, Mr. K. J. O'Neill, and Mrs. O'Neill, together with Mr. A. Maclean and Miss Hutchins, from Unilever.

In the afternoon the ladies visited the soap factory while the members were taken on a tour of the Merseyside power station by the station superintendent and his staff. The main interest of the visit was the supply of process steam over long distances to the various factories of the group—the steam having first been utilized for power generation. This proved an interesting study in economics as was shown during the question period which followed the meeting.

The members later rejoined the ladies at the Bridge Inn for afternoon tea, during which Mr. G. Prentice (Chairman of the Branch) thanked Unilever for their hospitality. His remarks were endorsed with applause by those present and the meeting terminated at 5.00 p.m.

North West England

Panel Meeting

Questions on the training of marine engineers; engine layout and design; machinery installation and ship operations were answered by a panel consisting of Commander G. Kenworthy-Neale, R.N.R. (Member), Mr. A. Blackburn, Mr. D. W. Bartlett (Member of Committee) and Mr. J. A. Smith, D.S.C., V.R.D., B.Sc. (Member of Committee), at a general meeting of the Branch held at 6.00 p.m., on Monday, 6th March 1967 at the Mersey Docks and Harbour Board Building, Pier Head, Liverpool.

The Chairman of the Branch, Mr. K. J. O'Neill, presided, and sixty-five members and visitors were present.

The panel were asked some very searching questions which stimulated further contributions and comment and a lively discussion of the general problems of the marine industry ensued.

After thanking the speakers, Mr. O'Neill commented that the subjects discussed had proved extremely interesting and the reception accorded the meeting showed that a similar discussion might well be a possibility for the future.

Following the vote of thanks, which was carried by acclamation, the meeting closed at 8.40 p.m.

General Meeting

A general meeting of the Branch was held on Monday, 3rd April 1967, at the Mersey Dock and Harbour Board Building, Pier Head, Liverpool, at 6.00 p.m. when the paper "Operating Experience with Large Modern Turbocharged Heavy Oil Engines" by G. McNee, B.Sc. (Member) and J. McNaught (Member) was presented by Mr. McNaught.

The Chairman of the Branch, Mr. K. J. O'Neill, presided and ninety-two members and visitors were present.

Before the presentation, the Chairman asked members to make a note that on 3rd October 1967 Mr. J. Stuart Robinson, M.A., Director and Secretary of the Institute, would be in Liverpool to speak on the activities of the Council of Engineering Institutions. Members would be advised of further details in due course.

Mr. McNaught then made his presentation which was followed by a lively discussion in which some six members put a variety of questions to the speaker.

Northern Ireland Panel

A joint meeting with the local branch of the Institution of Mechanical Engineers was held in the Millfield Building of the College of Technology, Belfast, on Tuesday, 18th April 1967 at 7.00 p.m., with Mr. D. H. Alexander, O.B.E., F.C.G.I., M.Sc., Wh.Sc. (Local Vice-President, I.Mar.E.) in the Chair. The audience numbered seventy.

The speaker at the meeting was Mr. F. G. West, B.Sc., who presented his paper "Design and Construction of Offshore Drilling Outfits" which was illustrated by a colour film, "The Underwater Search". An interesting discussion then took place.

Mr. G. R. Harvey, M.Sc. (Associate Member, I.Mar.E.), Honorary Secretary of the local branch of the Institution of Mechanical Engineers, proposed the vote of thanks.

The meeting closed at 9.15 p.m.

Scottish

A general meeting of the Branch was held at 6.15 p.m. on Wednesday, 22nd March 1967, at the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, when Captain N. J. H. D'Arcy, R.N. (Member of Council) presented the 1966 Parsons Memorial Lecture "The Prospect for Steam Propulsion".

Mr. W. McLaughlin, the Chairman of the Branch, presided and extended a welcome to the eighty members and visitors present.

In his presentation, Captain D'Arcy highlighted the salient points from his paper and this gave an opportunity for a most intresting and lively discussion. Many points were discussed in detail, including placing the responsibility for the designs of machinery and boilers in the hands of the supplier of major items of machinery instead of with the shipbuilder; the use of dirty and heavy fuels against the economies of cleaner fuel; reheat installations; fuel consumptions; the use of a single boiler with a "get you home" boiler as against two boilers of equal size for main propulsion; nuclear propulsion; contra-rotating propeller systems and the Paraplan gear system as designed at Pametrada.

The author, in his own and very attractive style, gave very satisfactory replies to all the questions raised.

The vote of thanks which was proposed by Mr. R. Beattie (Local Vice-President) was received with acclamation and the meeting closed at 8.10 p.m.

West of England

The Branch held its third Annual Joint Meeting with members of the Royal Institution of Naval Architects on Wednesday, 19th April 1967, in the New Lecture Theatre, City of Bath Technical College, at 7.00 p.m., when the paper "Ships for Containerized Cargo" by A. Killen (Member, R.I.N.A.) was presented by the author.

Captain A. A. C. Gentry, R.N. (Chairman of the Branch) presided and welcomed the sixty-two members and guests who were present.

Mr. Killen opened by saying that the great aim of containerization was to cut down the time a ship spent in port by making use of the ship as a transporter of goods rather than as a floating warehouse. In some cases up to fifty per cent of cargo transportation costs were incurred in port.

Containerization was not new and had been in use for more than sixty years, but development had accelerated since the Second World War.

Mr. Killen gave examples of container vessels from all parts of the world, illustrating these examples by the use of slides. Finally he discussed various design considerations for the modern container ship.

A lively and interesting discussion followed touching on many topics, including the economics of the subject and insurance difficulties. It was agreed that there were very many problems to overcome.

The vote of thanks was proposed by Sir Alfred Sims, K.C.B., O.B.E., M.I.Mar.E. (Vice-President, R.I.N.A.), Director General Ships, Ministry of Defence, who also paid tribute to the officers of the two institutions who had arranged the meeting. He expressed the hope that future meetings would take place every six months rather than annually.

The meeting closed at 8.45 p.m.

Overseas

Calcutta

Annual General Meeting

The Annual General Meeting of the Branch was held at 6.30 p.m. on 20th February 1967, at the British Council Lecture Hall. Mr. B. Hill (Local Vice-President) was in the Chair. The items on the agenda were discussed, a record of which follows.

The Statement of Accounts for the year ending 31st December 1966 was unanimously approved, being proposed by Mr. A. Sen Gupta and seconded by Mr. S. Chandra.

For the three existing vacancies on the Committee, seven nominations were received. Ballots were held and Messrs. K. S. Chetty, V. R. Rajagopalan and D. C. Agnihotri were elected.

The Committee for 1967 is therefore as follows:

Local Vice-President: B. Hill
Committee: D. C. Agnihotri
K. S. Chetty
K. S. Oberoi
V. R. Rajagopalan
K. Ramakrishna
S. V. Ramchandari
T. K. T. Srisailam
C. Tye
D. Vincent
Honorary Secretary: J. E. D'Souza
Honorary Treasurer: K. D. Pradhan

Mr. K. Ramakrishna was elected Honorary Auditor for 1967, being proposed by Mr. V. R. Rajagopalan and seconded by Mr. D. Vincent.

The Annual Report giving the activities of the Branch for the year 1966 was read to all present by the Chairman.

It was decided that one social gathering should be held during the year, the date being fixed by the Committee.

The meeting ended at 7.45 p.m. with a vote of thanks to the Chair.

Hong Kong

Dinner and Dance

A Dinner and Dance was held by the Branch at the Harbour Room of the Mandarin Hotel, Hong Kong, on Tuesday, 21st February 1967. One hundred and thirty-nine members and guests and their ladies attended and were received by the Chairman and Local Vice-President, Mr. W. Grieve and Mrs. Grieve, supported by the Vice-Chairman, Mr. E. L. Green and Mrs. Green.

This was one of the last Institute functions attended by

It was also agreed that a nomination of Mr. E. L. Green for the office of Local Vice-President for Hong Kong, should be placed before the Council for consideration.

Hong Kong

The Dinner and Dance held by the Branch on 21st February 1967 was one of the last Institute functions attended by the late Mr. W. Grieve before his untimely death on 29th March. With Mr. Grieve (third from left), who was Chairman and Local Vice-President of the Branch are (reading from left to right): Mrs. E. L. Green, Mr. E. L. Green (Vice-Chairman), Mrs. Grieve, Mr. L. T. Williams (Member of Committee) and Mrs. R. Wilson

Mr. Grieve before his untimely death on 29th March 1967.

At the conclusion of dinner, the Chairman welcomed the company and during his remarks reminded them that since the Institute was nearing eighty years of age it could hardly be accused of being precipitate in holding this, its first public social function in Hong Kong. On behalf of the Branch Committee and himself he thanked the organizing committee, Messrs. L. T. Williams, G. W. Bennett and P. E. J. Davy for their hard work which had resulted in the happy evening now being enjoyed by those present.

Music was provided during the evening and for the dancing by one of the hotel's resident bands. During a respite from dancing Mr. Tony Hancock, the well known entertainer, gave a topical and enlivening performance.

The evening's festivities closed at about 2.00 a.m. with expressions of general satisfaction on all sides and it was sincerely hoped that the occasion could become an annual event. The Committee were certainly heartened by the success of this, their first venture of such a nature.

Student Meeting

The first student meeting of the Branch was held on Wednesday, 22nd March 1967. A paper entitled "Some Aspects in the Operation and Maintenance of Ferry Vessels in Hong Kong" by E. C. K. Young, B.Sc. (Associate Member) was very well presented by the author to an audience of seventy-two.

Committee Meeting

At a meeting of the Committee held on Tuesday, 18th April 1967, Mr. E. L. Green and Mr. L. T. Williams were unanimously appointed as Chairman and Vice-Chairman of the Branch respectively.

Madras

Annual General Meeting

The Annual General Meeting was held on 17th March 1967 at the Seafarers' Club, Madras. Elections were held for office bearers and Committee for 1967. The Committee is now constituted as follows:

Local Vice-President: K. Parthasarathy
Chairman: A. T. Joseph
Committee: A. Dutta
S. Kasturirangan
J. Mathew
I. M. Ras
Honorary Secretary: V. K. Desai
Honorary Treasurer: T. S. Govindarajulu

It was agreed that four technical meetings should be held during the year and that Committee meetings should be held at about six-weekly intervals.

Mr. K. S. Subramaniam of the Delhi Branch was present at the meeting and at the conclusion of the formal proceedings gave an illuminating talk on standardization activities connected with hull construction and marine engineering.

St. Lawrence

Annual General Meeting

The Annual General Meeting was held at the Board of Trade Club, Montreal, at 5.30 p.m. on 30th January 1967. The retiring Branch Chairman, Mr. D. L. Findlay, opened the meeting with a review of the Branch's activities during 1966.

The minutes of the previous Annual General Meeting were read and adopted on the motion of Mr. T. R. Bradley, seconded by Mr. W. P. Graham.

The Chairman of the Papers and Meetings Committee presented his reports without comment from the membership.

The Honorary Treasurer presented his financial report for the fiscal year of 1966 and Mr. T. R. Bradley and Mr. R. Gentles were appointed to audit the accounts. The auditors declared the Branch's accounts conformed to the Honorary Treasurer's records.

A ballot was held for the election of Committee members, nine nominations having been received for the five vacancies on the Committee. The following were elected: Messrs. T. R. Bradley, W. P. Graham, R. T. Hesketh, R. Lyle and K. Wilson. There being no other nominations, Messrs. K. C. Hamilton and H. A. Sledge were re-elected Honorary Secretary and Honorary Treasurer respectively.

The Meetings Chairman, Mr. D. L. Findlay, outlined to the membership the basic details for the 1967 Technical Conference and also informed members of the accommodation available. He explained the concept of the Divisional Conference business meetings, in reply to questions from the floor.

The meeting closed at 6.20 p.m.

At an Executive Committee Meeting immediately following the Annual General Meeting, Mr. W. P. Graham was elected Chairman of the St. Lawrence Branch for the year 1967. The Committee for 1967 is therefore as follows:

Chairman: W. P. Graham
Vice-Chairman: T. R. Bradley
Committee: J. R. J. Boddington
R. T. Hesketh
R. Lyle
Lt. Cdr. C. J. J. McLauchlan, B.Sc. R.C.N.
W. A. Mason
K. Wilson
Honorary Secretary: K. C. Hamilton
Honorary Treasurer: H. A. Sledge

Visakhapatnam

Annual General Meeting

The Annual General Meeting was held at 7.00 p.m. on Friday, 24th February 1967 at the residence of Mr. H. C. Raut, B.Sc. (Local Vice-President).

After welcoming the eighteen members present, Mr. Raut invited the Honorary Secretary, Mr. K. K. Banerjee, M.Eng., to read the minutes of the previous Annual General Meeting. The Chairman of the Branch, Commander V. S. P. Mudaliar, I.N., proposed that the minutes be confirmed and this was seconded by Mr. P. K. Banerjee. There being no objections the minutes were confirmed and the Honorary Secretary proceeded to read the Annual Report for the year 1966-67.

He appealed to members to contribute technical papers for publication in the Indian Supplement and announced that it had been decided to introduce a correspondence section in the Supplement, though only letters on technical matters and of a sufficiently wide appeal would be published.

Mr. M. M. Nambiar proposed that the report be adopted. This was seconded by Mr. R. P. Chitra and the report was adopted by acclamation.

Mr. A. Prakash, B.Sc., the Honorary Treasurer, then read his statement of accounts. The Local Vice-President expressed his satisfaction with the very economical spending and on the proposal of Mr. R. P. Chitra, seconded by the Chairman of the Branch, the statement was adopted.

No objections being raised against any of the nominations to vacancies on the Committee, on the proposal of Mr. K. K. Banerjee, seconded by Mr. P. K. Banerjee, Messrs. M. M. Nambiar, D. S. Sheth and R. S. Grewal were elected.

Mr. K. K. Banerjee and Mr. A. Prakash were then re-elected as Honorary Secretary and Honorary Treasurer respectively and Mr. K. K. Banerjee requested Cdr. Mudaliar to continue as Chairman of the Committee. This was carried unanimously.

The Committee for the year 1967-68 is therefore composed as follows:

Local Vice-President: H. C. Raut, B.Sc.
Chairman: Commander V. S. P. Mudaliar, I.N.
Committee: P. K. Banerjee
R. S. Grewal
M. M. Nambiar
K. K. Narayanan
D. S. Sheth
Honorary Secretary: K. K. Banerjee, M.Eng.
Honorary Treasurer: A. Prakash, B.Sc.

Mr. Raut then invited suggestions for improvements in the working of the Branch. Among the suggestions received were that there should be more technical visits and that technical discussions should be arranged.

There being no further business to transact, the Local Vice-President thanked the out-going Committee and welcomed the new Committee. He remarked that within a few years marine engineers would have to take more responsibility and that the Branch could contribute to the progress of marine engineering in India. He hoped that members would not mind the slight hardship caused by the increase in subscriptions due to devaluation of the rupee but would try to bring in many more new members.

The Chairman of the Branch then proposed a vote of thanks to Mr. Raut which was carried with applause and the meeting closed at 8.30 p.m.

After the meeting, members adjourned to the lawn to join their ladies and guests for a buffet supper.

Mr. P. V. G. Raju, Minister for Cultural Affairs, Andhra Pradesh, was the chief guest and he exhorted the members to work for the development of the country and marine engineering in particular.

The members departed at 11.00 p.m. after thanking Mr. and Mrs. Raut for their hospitality.

Western Australia

Discussion Meeting

"Containerization" was the subject of a discussion meeting held by the Branch on Wednesday, 12th April 1967, in the Board Room of the Flying Angel Club, Fremantle, attended by twenty-six members and eight visitors. Several members being closely connected with this important development, a most interesting discussion ensued which Mr. E. E. Freeth, Chairman of the Branch, reluctantly broke up when time ran out.

Addition to Programme of Meetings

14th June — Social Film Evening for members and their ladies, to be held in the Auditorium of the Fremantle Port Authority Building at 8.00 p.m.

Election of Members

Elected on 12th April 1967

MEMBERS

Elections

Thomas John Browne, Eng. Cdr., D.S.M., R.N.
William Sinclair Chalmers
Gerald Raymond Collings
James Crawford, B.Sc.
Patrick Linden Derrick, B.Sc.
Michael Hugh Evans Gregson

James Mellor Grundy
Cyril Thomas Hardie
Robert Harkness
Raymond Harold Leeson, Lt. Cdr., R.N.
Alan Gibb McKenzie
William Keith Mackie
Murray Dunbar McNicol
John Denis Richmond
Ian Earle Sharp

Transferred to Member from Associate Member
Joseph Emile George Donat Gravel
Thomas Wilfred Hindle
John Joseph Hutcheson
Leslie Ronald Hyett
Herbert Roland Percy, Lt. Cdr., R.C.N.
Arthur Ronald Scott

Transferred to Member from Associate
James Pendlebury
Constantinos Vitsaxakis

ASSOCIATE MEMBERS
Elections
Kulwant Singh Bhasin, Lieut., I.N.
James Neil Boyle
Patrick Francis Fernandes
Peter James Fowler, Eng. Lieut., R.N.
Raymond Harold Gee
Hon Pui Tong
Geoffrey Hopkins, Eng. Lieut., R.N.
Hung Piu Kwong
Richard Jean Lajoie
Leonard John Lonie, B.Sc.
Prahlad Alimchand Mirchandani
William Raymund Nomchong
George Alfred John Penhaligan
Hans Elias Schreiber
Gordon John Cordiner Shaw
Pieter Cornelis Smits
Mark Sabino Soares
Remo Torchio, Dott. Ing.
Carr Wing Wong

Transferred to Associate Member from Graduate
Roy Gibson
Anthony Francis George Kinkead
Edmund Denis Marsden
Michael Maughan
Edward Roger White
Robert Ivor Woodroofe, Lieut., R.N.Z.N.

Transferred to Associate Member from Student
Martin Robert Ievan Evans
Christopher Matthews
Frederick Joseph Parle
John Samuel Thompson

Transferred to Associate Member from Probationer Student
Kenneth Millson Brown
Kenneth Roberts
James Doggart Vance

ASSOCIATES
Elections
Donald Butler
Patrick Denis Donoghue
Hubert Leo Saldanha, Sub. Lieut. (SD) (SW), I.N.
Roy Francis Smith
Frederic Charles Douglas Woodward

Transferred to Associate from Graduate
James Roy Laird Webster

GRADUATES
Elections
Redmond Patrick George Baylis
Maurice Harwin Bosier
James Henry Kelly
Lawrence Amatari Yibowei

Transferred to Graduate from Student
Peter John Goodwin
Michael John Johnson
Leung Chak Tong
Brian Norman Scott

STUDENT
Elections
Syed Shahid Ali
John Gilchrist Black
John Michael Brady
Philip Roger Brooks
George William Campbell
Eivind Christoffersen
Stephen Philip Clarke
Nigel de Montfort Fallows
Richard Philip John Gladwin
Ian Harvey
Gavin Aleck Henderson
Peter Henwood
Antony George Higgins
Michael John Holmes
Theodore D. Kokkinos
David William Lee
Philip Cornelius McKiernan
Peter William Marchant
David Lane Meadows, Sub. Lieut., R.N.
James Patterson
Martin Charles Peek
Gordon Raeburn
Ian McLean Russell
David Saile
Warren James Scott
John Lorimer Thomas
Richard John Langley Ward
Andrew Aked Wilson

Transferred to Student from Probationer Student
Ian David Badenoch
Peter Ross Noel Barrar
James Martin Culkin
Anthony Victor Davies
Leslie William Douthwaite
Kenneth Graham
Malcolm Kay Peck
Stanley Edward Robinson

PROBATIONER STUDENTS
Elections
Michael Charles Ashworth
John Barron
Raymond Philip Bates
Richard David Bingham
John Arthur Chapman
Stephen Leslie Cocker
Nigel Graham Copps
Roger Marlows Creasy
Trevor John Croft
James Dixon Dawson
John Clark Devine
Michael Dunne
Brian Philip Easton
Owen Robert English
Jonathan Eric Fielder
Arthur Glanville

Michael Jeffrey Goodwin
David Gouldstone
Neville Howard Greenwood
Barry Ritson Hails
Roger Frederick Harris
Terence Robert Hill
Alan Arthur Hull
R. W. Jarmain
Peter Lloyd Jones
William Howell Jones
Martyn Geoffrey Richards Lewis
Paul Dennis Lumb
Gordon Alexander McGrath
Grahame Mackay
Graham Ross McKee
K. Mackness
Michael Manley
Paul Wright Maskall
Iain Murray
Robert Charles Pearce
William Arthur Ridealgh
Donald Ross
Richard John Ruddle
John Alan Shorman
Colin James Boughton Smith
David Warwick
David Edward Watson
David Ashley Wright
Keith Wright
David John Yates

OBITUARY

HORATIO NELSON PEMBERTON (Vice-President)

An appreciation by J. McAfee (Member)

Nelson Pemberton had an outstanding career as Chief Engineer Surveyor of Lloyd's Register of Shipping and acquired an international reputation. In the Institute his services on Committees and as a Member of Council, of which he became Chairman, left an enduring mark. On retirement from Lloyd's Register at the end of last year he was elected Chairman of the Council of Engineering Institutions and thus became the virtual head of the whole engineering profession in this country.

He regarded this not as a personal honour alone but also as a tribute to the Institute and the marine engineering profession. His sudden death after so short a time in office is a tragic loss to us all. Yet, even in that brief period he made his mark in C.E.I. With typical energy he had drawn up a lengthy statement on policy which he presented to his last full meeting of the Board with all his usual vigour and sense of command. Looking back it was all a fitting epilogue in which his ability and skill as a chairman appeared to the full. His statement was also a reflection of his own philosophy and certainly this is a more enduring memorial than anything which can be written now.

It was in this capacity as chairman that those who knew him less intimately will probably remember him best. He had a kind and natural way of dealing with committee members and could quickly grasp the essential points in a long debate and bring the recommendations to a happy and acceptable conclusion.

In private life he was a man of simple tastes delighting above all else in the pleasure of his own home. At a small private party after his retirement from Lloyd's Register he rose to his feet to make a brief informal speech, in the course of which he turned towards Mrs. Pemberton and smilingly suggested that whatever success he had achieved was largely due to her help and encouragement. The compliment was the more charming because he never wore his heart on his sleeve and disliked display of emotion.

In his son and daughter, both of whom have taken up professional acting careers, he found tremendous pleasure and was never happier than when taking a few friends to the theatre to enjoy a performance in which one or other of his children was acting.

His busy life had left him little time for other pursuits and he regretted that it was only recently that he had begun to discover the pleasures of good music and was beginning to build a library of the world's classics. It was of this that we spoke and not engineering when he paid his last visit to the building where we first met over half a lifetime ago. As he was leaving I jocularly remarked on his youthful appearance. Two days later he was dead. Once the end was inevitable his passing was swift but I think this is how he would have wished to go. It is sad that he could not complete the work on which he had set his mind nor achieve the honours which would undoubtedly have been his.

HORATIO NELSON PEMBERTON (Member 12672) died on 6th April 1967. He was sixty-five years old.

He served his apprenticeship with Blair and Co., Stockton on Tees, and with Scott's Shipbuilding and Engineering Co., Greenock. In 1930, after a period of service with the Merchant Navy, during which he gained his Extra First Class Combined Certificate, he joined Lloyd's Register of Shipping as a ship and engineer surveyor. Following service in various ports at home and abroad, he was promoted to Principal Surveyor in 1947 and in 1957 he became Chief Engineer Surveyor, serving in this capacity until his retirement in January 1967.

During his ten years as Chief Engineer Surveyor to the society, he was responsible for the supervision of the society's engineer surveyors throughout the world and for the standards of design, construction and maintenance of ships machinery as governed by the society's rules. He also held overall responsibility for the society's work in the non-marine field.

Mr. Pemberton was elected a Member of the Institute in December 1949 and in 1951 was first elected to Council. He was again elected a Member of Council in 1953 and 1958. He became a Vice-President for the United Kingdom in 1965 and served as Chairman of Council 1965-1966.

He carried out a great amount of committee work for the Institute from April 1953 when he was elected to the Education Group Committee, becoming the Committee's Vice-Chairman one year later, at which time he was also elected a Member of the Awards Committee.

In April 1955 he was co-opted as Chairman of the Education Group Committee and was elected a Member of the Special Committee for the nomination of Vice-Presidents in November 1955.

In December 1955, as the Institute's representative, he was elected to serve upon the Special Committee on the Application of Nuclear Power to Marine Propulsion.

Mr. Pemberton was awarded the Denny Gold Medal in 1960 for his paper *Marine Machinery Failures*. He was also the holder of the City and Guilds of London Institute Insignia Award in Mechanical Engineering (*Honoris Causa*) and in 1966 was awarded the M. C. James Medal by the North East Coast Institution of Engineers and Shipbuilders for his paper *Modern Trends in Classification Procedure and Practice,* presented in March of that year at a joint meeting with this Institute.

He was a Member of Council of the Institution of Mechanical Engineers, whose Thomas Lowe Gray Memorial Lecture he delivered in January 1953 under the title *Welding in Marine Engineering,* and was also a Member of the Institute of Welding, an Associate Member of the Royal Institution of Naval Architects and a Vice-President of the British Internal Combustion Engine Research Institution.

Among the governmental committees on which he served were the Admiralty/Atomic Energy Authority nuclear warships safety committee, the Ministry of Transport committee on the prevention of pollution of the sea by oil and the Ministry of Power nuclear safety advisory committee.

In 1960 he was a member of the United Kingdom delegation to the Safety of Life at Sea Conference. He was a member of the marine engineering and atomic energy committees of the British Ship Research Association and a member of the General Council of the British Standards Institution, also serving as Chairman of that Institution's Council for Codes of Practice.

From 1964 Mr. Pemberton served as the Institute's representative on the Board of the Council of Engineering Institutions and although it was only in January of this year that he assumed office as the Council's Chairman, he had already reviewed the policy of the Council and established guidelines for future development.

Stewart Alexander Anderson

Local Vice-President, Singapore

Stewart Alexander Anderson, O.B.E. (Member 6325) died on 28th October 1966. Elected a Member of the Institute in December 1929, he performed many years of valuable service as Local Vice-President for Singapore from 1953 to June 1966.

Mr. Anderson was born in 1906 and educated in Leith. He studied mechanical engineering at the Heriot Watt College, Edinburgh, and was subsequently apprenticed, for 5½ years, to Hawthorn and Co. Ltd. He served a further year as an engine draughtsman with Henry Robb Ltd., before taking up a sea career during which he obtained a First Class Board of Trade Certificate of Competency.

He joined Messrs. Ritchie and Bisset, consulting engineers and marine surveyors of Singapore, in 1926, as an assistant engineer and entered the partnership during 1932. He succeeded to the senior partnership in August 1952 in which capacity he served until his retirement on 31st August 1966. During this time he held surveyorships to the majority of the principal classification societies.

A member of the Scottish Company of the Singapore Volunteer Corps, he was, at the outbreak of war, seconded to the Sea Transport Office (Technical) as a civilian concerned with preparing and converting the local coastal fleets for special duties, as assistant to the Deputy Superintending Sea Transport Officer, Malaya. He escaped from Singapore, but was captured after two days at sea and spent the rest of the war in one of the worst camps in Sumatra, where he performed heroic work among the sick and dying.

Immediately upon his release he returned to Singapore and commenced putting the business back on its feet. During this period he acted on behalf of Lloyd's Register of Shipping until relieved by their own surveyor.

In 1964 he was decorated with the O.B.E. by Her Majesty The Queen at Buckingham Palace, and was also awarded the Bintang Bakti Masharakat by the Singapore Government.

In addition to his business commitments he was very interested in all that went on, particularly with the formation of the Polytechnic where he became one of the founders. All educational aspects interested him and among other things he was for many years corresponding member for the Institution of Mechanical Engineers and the Royal Institution of Naval Architects. As Local Vice-President of the Institute of Marine Engineers, he played a major roll in the formation of the Local Group, being its first President.

He was also a former Chairman of the Singapore/Malaya Joint Group of the Institutions of Civil, Mechanical and Electrical Engineers.

Always ready to impart of his knowledge and working of the area, he served on the boards of directors of several companies, notably: United Engineers 1952-1966 (Chairman 1956-1965); Singapore Cold Storage; Singapore Dairy Farm; Far East Oxygen and Acetylene Co.

Due to ill health he returned to the United Kingdom during July 1965 and underwent several major operations. He will be sadly missed by his many friends.

William Grieve

Local Vice-President, Hong Kong

William Grieve (Member 7312) Deputy Director of Marine, Hong Kong Government Marine Department, died in hospital after a brief illness on 30th March 1967. He was fifty-four years of age.

Mr. Grieve served an apprenticeship at the Engineering Laboratories of the University of Edinburgh, from 1927 to 1932, and with Brown Bros., Rosebank Iron Works, from 1932 to 1933. On completion of his apprenticeship he joined the Royal Navy. In January 1944, whilst serving in the rank of chief engine room artificer, he was mentioned in a despatch, for distinguished service. On leaving the Royal Navy in 1945, Mr. Grieve attended Poplar Technical College and, in 1946, gained the Institute Award of a Silver Medal for obtaining the highest marks in the Board of Trade Extra First Class Examination. From 1947 to 1950 he was engaged by the International Cold Storage Co. Ltd., as deputy superintendent engineer, in rehabilitation of their cold storage and food processing plants in Shanghai, Nanking, Hankow and Tientsin. In 1950 he was appointed as a surveyor of ships (engineer and ship) by the Hong Kong Government and promoted to senior surveyor in 1961, Assistant Director of Marine in 1962 and to Deputy Director of Marine in February 1967, the position he occupied at the time of his death.

His association with the Institute began as a Student Member, and he was transferred to full Membership in 1945. He played a major part in the formation of the Institute's Hong Kong Branch, acting as Chairman and Honorary Secretary at different times on the Branch Committee. He was the first Chairman of the Branch and was later, in 1966, appointed Local Vice-President for Hong Kong. He was also Vice-President of the Engineering Society of Hong Kong, a Member of the Institution of Mechanical Engineers, a Member of the Royal Institution of Naval Architects, an Associate Member of the British Institute of Management and a Member of the Hong Kong Management Association. He served as a trustee and a deacon of the Union Church of Hong Kong and a Committee Member of the Colony's European Young Men's Christian Association.

Mr. Grieve is survived by his wife and a daughter.

COMMODORE ARTHUR CECIL MONTAGUE DAVY, O.B.E., C.D., R.C.N. (Member 5399) died on 2nd March 1967. He was sixty-five years old.

He graduated from the Royal Naval College of Canada in 1920 and later attended the Royal Naval Engineering College, Keyham.

At the outbreak of war he was appointed director of shipbuilding at Naval Headquarters, Ottawa, and in 1941 became Director of Naval Engineering Development. In 1949 he was appointed Engineer-in-Chief, Naval Headquarters, Ottawa. He retired from the Navy in 1955.

Commodore Davy was the holder of the Order of the British Empire and the Canadian Decoration and was a former Western Field Secretary of the Engineering Institute of Canada. He was elected a Member of the Institute in September 1925. He leaves a widow, a son and a daughter.

ARTHUR DUNN (Member 19940) died on 4th May 1966. He was sixty-eight years old.

He served his apprenticeship from 1914-1917 in H.M.S. *Indus*, Mechanical Training Establishment, Devon, and, during the naval career which followed, rose from fifth class engine room artificer, in 1918, to Lieutenant (E). He gained his First Class Certificate of Service in 1948.

In 1952 he joined Overseas Tankships (U.K.) Ltd., serving with them as second engineer and later as chief engineer. He remained with the company until his retirement in 1962.

Mr. Dunn, who was also a Member of the Merchant Navy and Air Line Officers' Association and the Association of Retired Naval Officers, was elected a Member of the Institute in March 1958. His wife survives him.

VICTOR FRANK HARRIS (Associate 19801) died on 9th July 1966. He was fifty-two years old.

He served his apprenticeship with Harris and Webster (Melbourne) from 1928 to 1934 and became managing director of V. F. Harris Pty. Ltd., Melbourne in 1937.

He was elected an Associate of the Institute in January 1958. His wife survives him.

HENRY LOCKHART (Member 4932) died on 12th February 1967. He was eight-five years old.

From 1898 to 1903 he served his apprenticeship with the Fairfield Shipbuilding and Engineering Co. Ltd., Govan, after which he joined the Atlantic Transport Line as assistant engineer and served with them in all ranks up to junior second engineer.

After gaining his First Class Board of Trade Certificate in 1907, he was appointed chief engineer in Japan's first turbine steamer *Hirafu Maru*.

Later he joined the Union Iron Works, San Francisco, remaining there until 1912 when he returned to sea, as second engineer in R.M.S. *Niagara*, then being built at John Brown's, Clydebank, for the Canadian Australasian Royal Mail Line. He remained with the line until 1942, when he retired temporarily due to impaired health, serving in *Aorongi* and *Awatea*.

Recuperating sufficiently to take a shore position, he joined the Australian Commonwealth Government Service as liaison engineering officer, Army Fighting Vehicles Division, with which he remained until his retirement in 1947.

Mr. Lockhart was elected a Member of the Institute in September 1923. He was also a Member of the Royal Institution of Naval Architects.

FRANK WOOD ODDY (Member 8840) died on 18th February 1967. He was seventy-two years old.

From 1909 to 1913 he was apprenticed in H.M. Mechanical Training Establishments, after which he served as an engine room artificer from 1914 to 1920.

In 1921 he joined Elders and Fyffes Ltd., with whom he remained until his retirement in 1962, reaching the position of superintendent engineer.

Mr. Oddy, who was the holder of a First Class Board of Trade Certificate, was elected a Member of the Institute in February 1939. He was also a member of the Huddersfield Engineering Society. His wife survives him.

JOHN WILLIAM RAYMOND MCCARTHY (Member 17811) died on 17th February 1967. He was in his fifty-seventh year.

Apprenticed to Forsters Engineering Works, Brisbane, from 1926 to 1931, Mr. McCarthy, in the latter year, joined Evans Deakins and Company, constructional engineers, and remained with them until 1943. In December of that year, he became a seagoing engineer with Howard Smith Ltd., serving in all grades from third to chief engineer. He gained a First Class Steam Certificate in 1953 and a Motor Endorsement in 1956.

Mr. McCarthy was elected a Member of the Institute in September 1956 and was also a Member of the Australian Institute of Marine and Power Engineers.

He is survived by his wife.

ROBERT MCDONALD, B.Sc. (Member 7126) died on 31st March 1967 at the age of fifty-four.

Mr. McDonald served his apprenticeship with Palmers Shipbuilding and Iron Company from 1928 to 1933. In the latter year, he joined Royal Mail Lines Ltd. as a seagoing engineer and served in various grades up to second engineer. He gained his First Class Motor Certificate in 1939 and a First Class Steam Endorsement three years later.

In 1947, he was appointed a lecturer in the engineering department at East Ham Technical College, but later moved to South Shields.

First elected to membership of the Institute as a Student in July 1932, Mr. McDonald became a full Member in May 1944. He served as Honorary Treasurer of the North East Coast Branch from 1961 to the time of his death.

He leaves a widow.

JACK SHERWOOD NELL (Member 9855) died on 31st March 1967. He was forty-eight years of age.

After a general education at St. Dunstan's College, Mr. Nell received his technical education at the London Technical College. From 1935 to 1939 he was apprenticed to the General Steam Navigation Co. Ltd., with whom he afterwards served at sea, as third and second engineer, until December 1943. In 1944, he entered the Royal Navy and, with the rank of Lieutenant (E), R.N.R., served until May 1946 in H.M.S. *Prince Baudouin* and *Bulolo*.

He left the Navy to become a director of the London Yacht Company, but in 1954 took up an appointment with the Regent Oil Company, with whom he remained as Chief Marine Engineer until the time of his death.

Mr. Nell was elected an Associate of the Institute in March 1944 and transferred to corporate membership in December 1948; he was also a Fellow of the Institute of Petroleum. The paper, *Modern Oils in Marine Service*, of which he was the co-author, was presented to the then Scottish Section of the Institute of Marine Engineers in January 1961 and was published in the *Supplement to Transactions* in February of the following year.

Mr. Nell is survived by his wife, a son and two daughters.

JOHN PREST (Member 12876) died on 14th May 1966. He was sixty-eight years old.

After serving his apprenticeship with Smith's Dock Ltd., North Shields, he joined Messrs. W. Runciman and Co. He gained his First Class Steam Certificate in 1923 and in 1924 joined the New Zealand Shipping Co. Ltd. In 1935 he gained his Motor Endorsement.

His first appointment as chief engineer was in s.s. *Remuera* in 1940. Later Mr. Prest was appointed to m.v. *Orari* and was awarded the O.B.E. for his part in bringing this vessel safely into Malta after being mined in the Mediterranean.

After the war, he stood by the building of a new m.v. *Sussex* in Glasgow and served in the vessel until his retirement in 1958.

Mr. Prest was elected a Member of the Institute in June 1950. He is survived by his wife.

ALEXANDER MICHIE RIDDELL (Member 7693) died on the 21st November 1966. He was seventy-four years old.

He served his apprenticeship with Tate and Lyle and joined the Royal Naval Reserve as an Engineer Sub-Lieutenant at the outbreak of the Great War. He was invalided out of the Royal Naval Reserve but continued at sea in the Merchant Navy, gaining his First Class Board of Trade Certificate. After the war he joined R. and H. Green and Silley Weir, subsequently becoming manager of their central works, Royal Albert Dock.

In 1935 he was appointed manager of the Kort Propulsion Co. Ltd. and joined their board of directors in 1942. He retired in December 1959.

Mr. Riddell was elected a Member of the Institute in November 1934.

CECIL WILFRED WHITELEY (Member 5040) died on 24th February. He was seventy-six years old.

After serving his apprenticeship with the Thames Ironworks, London, he saw sea service for the next nine years, serving with Ellerman and Bucknall Ltd. and with the P. & O. Steam Navigation Co. Ltd.

In 1924 he joined J. Lyons and Co. as a foreman engineer, remaining with them until 1926, when he joined the Wimbledon Council as superintendent of the Baths Department, the position he held until his retirement in 1955.

Mr. Whiteley, who held a First Class Board of Trade Certificate, was elected a Member of the Institute in March 1924. He leaves a widow.

JOHN WYLD, D.S.O. (Member 9582) died on the 11th December 1966.

He was born in Glasgow in 1896 and after serving his apprenticeship with Barclay, Curle and Co. commenced his career at sea in 1918 as a junior engineer in the Royal Fleet Auxiliary *Cherryleaf*.

At the end of the Great War he joined the Eagle Oil and Shipping Co. Ltd. gaining his First Class Board of Trade Certificate in 1922 and Motor Endorsement in 1936.

In 1934 he came ashore to help supervise construction of some new Diesel tankers, and returned to sea in 1935 as a second engineer, being promoted to chief engineer in 1937.

In 1941 he was chief engineer in s.s. *San Felix* when she was torpedoed off Greenland. In 1942 he was appointed chief engineer in s.s. *Ohio*. He received the D.S.O. for his meritorious service in helping to bring the ship within reach of Malta after she had received hits from bombs, torpedoes and parachute mines. He also received the Thomas Gray Memorial Award for gallantry.

In 1943 he came ashore for special duties and was appointed assistant engineer superintendent in 1945. He was appointed senior engineer superintendent in 1951 and retired in 1958.

He was elected a Member of the Institute in March 1943 and, later in that year, Vice-President for the Merchant Navy.